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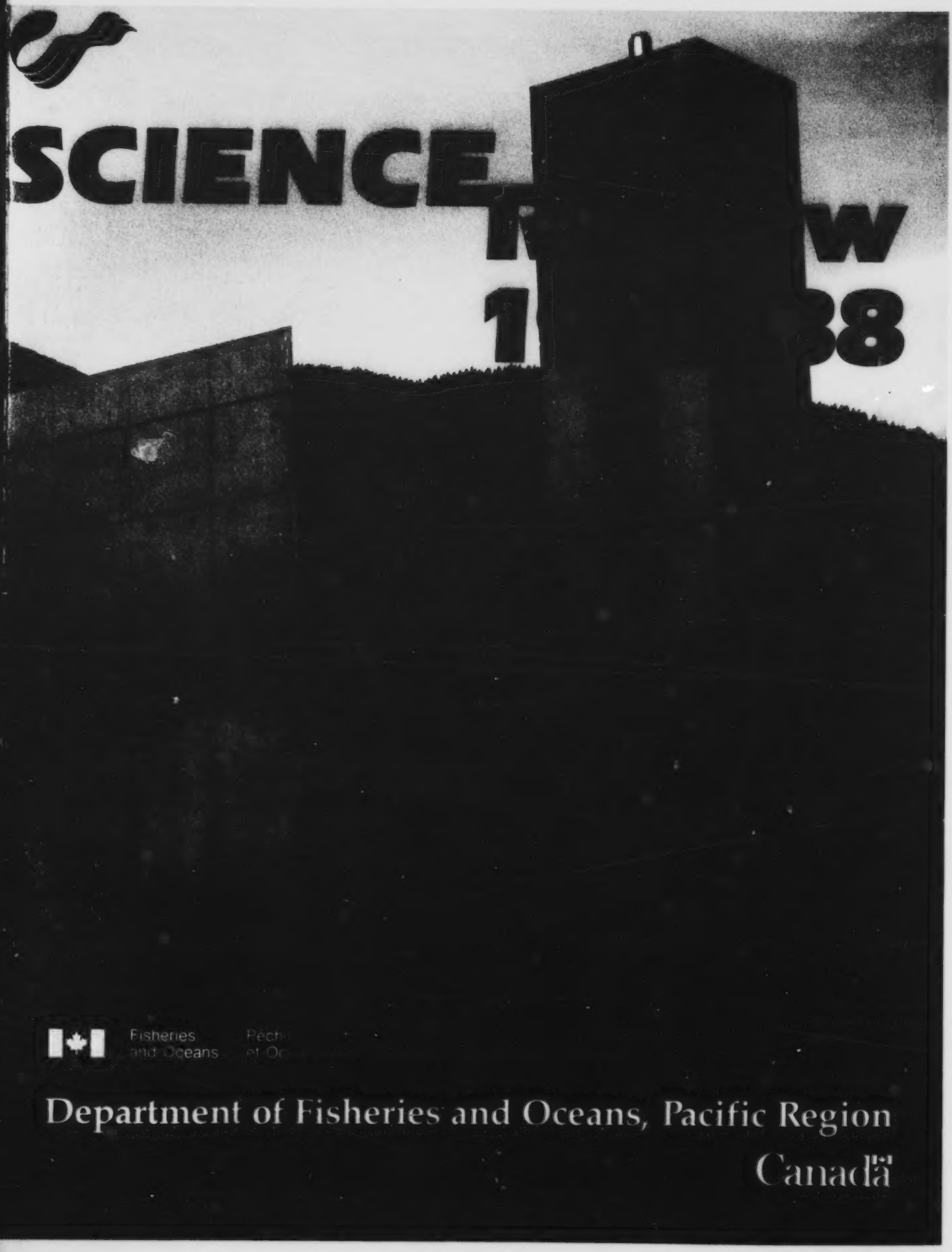
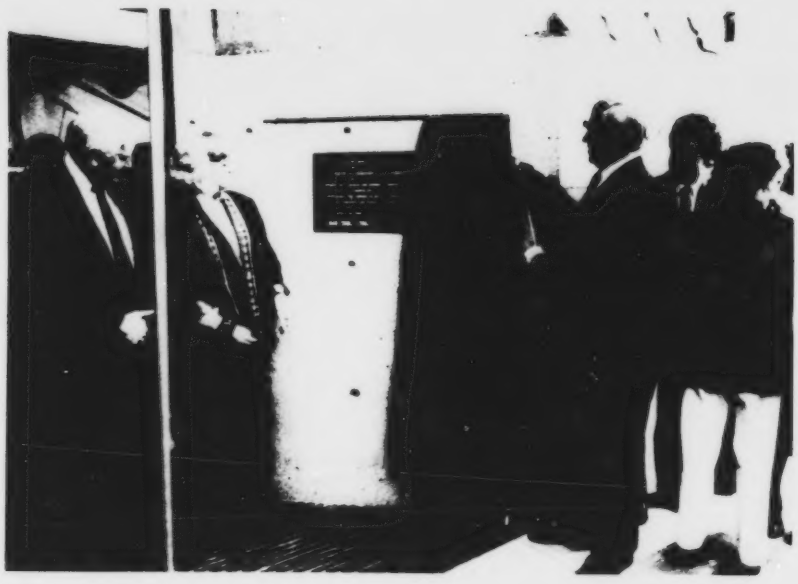


Fisheries and Oceans / Pêches et Océans

Department of Fisheries and Oceans, Pacific Region

Canada

SCIENCE Review 1987-88



Plaque commemorating official opening of the new West Vancouver Laboratory building is unveiled by the Minister of Fisheries and Oceans, Tom Siddon.

SCIENCE Review 1987-88

Fisheries and Oceans / Pêches et Océans

Department of Fisheries and Oceans, Pacific Region

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This report describes the programs and activities of the Science Sector, Pacific Region, Department of Fisheries and Oceans during the fiscal year 1987/88.

It is intended to review the activities of Biological Sciences Branch (headquartered at the Pacific Biological Station with facilities at West Vancouver, Cultus Lake and the Institute of Ocean Sciences) and Hydrography and Physical and Chemical Sciences at the Institute of Ocean Sciences.

Science review 1987/88 was produced by Communications Branch, Pacific Region; Kelly Francis and Kate Glover, editors.

COVER: *Temporary office and laboratory space at the West Vancouver Laboratory site has been replaced by this new facility, officially opened by the Hon. Tom Siddon, Minister of Fisheries and Oceans on March 26, 1988.*

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Introduction

In 1987/88, a rigorous program of scientific studies was carried out at the Pacific Biological Station (PBS), Nanaimo; the Institute of Ocean Sciences (IOS), Sidney; the West Vancouver Laboratory (WVL); and at satellite facilities located at Cultus Lake, Vancouver, and elsewhere. These studies addressed priority long term and applied research topics in support of the Department of Fisheries and Oceans (DFO) mandate related to the fisheries resource, the oceans and hydrographic activities on the west coast, inland waterways and in the western Arctic.

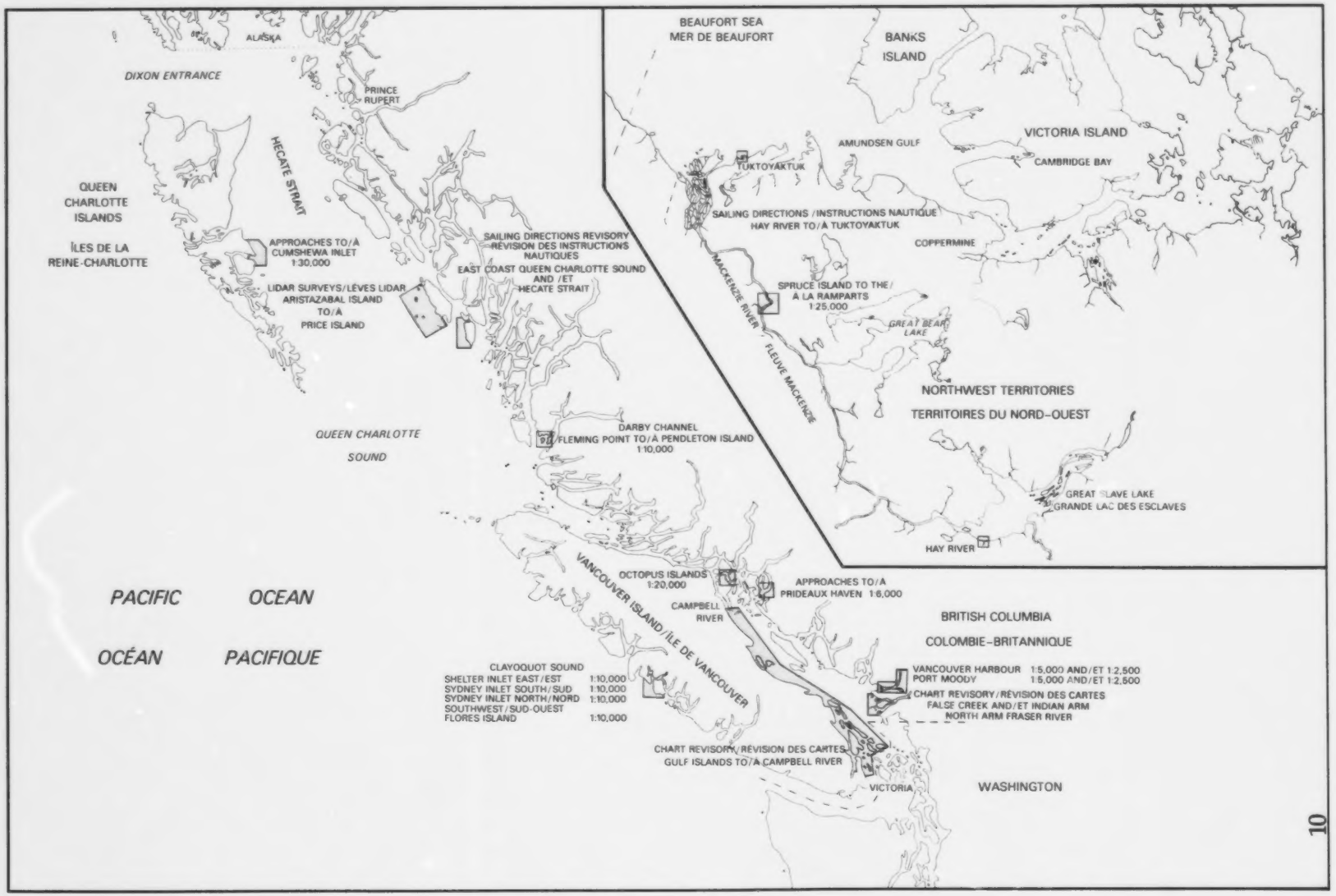
Of particular concern were studies related to understanding and modelling ocean processes, climate and greenhouse gas effects research, acoustic research in support of fish stock and habitat assessment activities, studies supporting the rapidly growing aquaculture industry, and vigorous programs of field hydrography, cartography and production of special publications for mariners.

During 1987/88, a major multidisciplinary program on Marine Survival of Salmon (MASS) was initiated in the vicinity of Barkley Sound, Alberni Inlet and the west coast of Vancouver Island. It involves collaboration of oceanographers, fisheries biologists, hydrographic and engineering staff collaborating to elucidate factors influencing survival and abundance of young salmon in the initial phases of oceanic life and during their coastal outmigration.

In addition, an extremely successful field season completed in the Beaufort Sea under the Northern Oil and Gas Program (NOGAP) focused on hydrocarbon fate and effects studies which will be of value for future exploratory and environmental impact assessment considerations.

Pacific Region science activities of the DFO are administered by a Regional Director of Science and a Science Executive staffed by Branch Directors as indicated in the organization chart included in this report. The group reports to the Regional Director General who, in turn, reports to the Assistant Deputy Minister of Science in Ottawa. National coordination with the other five regions is achieved through a National Science Director's Committee.

INSTITUTE OF OCEAN SCIENCES



Pacific Region 1987 Hydrographic Survey Program
1987 Programme De Leves Hydrographique De La Région Du Pacifique

Hydrography

Canadian Hydrographic Service, Pacific Region, has responsibility for surveying the Pacific coast of Canada, the waters of the western Arctic and inland navigable waters as far east as the Saskatchewan/Manitoba border. In addition to nautical charts, CHS also publishes related publications including tide tables and sailing directions. Tidal and current surveys are carried out to ensure that reliable data for tidal predictions and other specific purposes are available. Included in the regional mandate is instrument development and industrial liaison.

Among the highlights of the year was the Vancouver Harbour survey. The party used ISAH navigation, logging and processing systems, considered world leaders, and developed in Canada by Quester Tangent Corp. in cooperation with the Canadian Hydrographic Service and Supply and Services Canada. Successful integration of science sectors was illustrated through the team effort to convert an ageing side-scan sonar system into an effective stock assessment tool. The equipment was used for the Marine Survival of Salmon (MASS) Project.

Field Hydrography

Changes to traffic routes, types and sizes of vessels, harbours, bottom topography and coastline require new surveys or resurvey.

A major survey party, assigned to the barge L. PACIFICA undertook a resurvey of Vancouver Harbour from April to October. By the end of the season, the harbour was resurveyed from First Narrows Inlet to the City of Port Moody for new editions of charts 3482, 3494, and 3495. *(Contact: A.R. Raymond.)*

A second major survey party was assigned to the barge PENDER, from April to October for resurveys on the west coast of Vancouver Island. While these are continuing surveys, those of Millar Channel; Shelter, Stewardson, and Holmes inlets; and Hot Springs Cove were completed. *(Contact: J.V. Crowley.)*

From CSS RICHARDSON, a survey party conducted a large-scale resurvey of a portion of Prideaux Haven for revision to a chart sheet in Chart Atlas 3312. Later in the season, surveys were continued on the approaches to Cumshewa Inlet. *(Contact: F.A. Coldham.)*

In a cooperative project with Canadian Coast Guard (CCG), the City of Hay River, Alberta, and Public Works Canada, a resurvey of the southern approaches to the ramparts on the Mackenzie River was conducted. *(Contact: F.A. Coldham.)*

Revisory surveys were conducted in the Gulf Islands, from Nanaimo to Campbell River on Vancouver Island, in False Creek, Indian Arm, and the North Arm of the Fraser River. *(Contact: G.E. Richardson.)*

A resurvey in Darby Channel was conducted as a result of a rock reporting. *(Contact: F.A. Coldham)* Another, of Octopus Islands, was carried out for a similar reason. *(Contact: G.H. Eaton.)*

Navigational and logistical support was given to the MASS project. *(Contact: M.V. Woods.)*

A Light Detection and Ranging (LIDAR) survey was carried out under contract in the area of Aristazabel Island and Price Island. *(Contact: B.M. Lusk.)*

In preparation for 1988 surveys in Queen Charlotte Strait and Sound, a coastline plot was produced under contract. *(Contact: B.M. Lusk.)*

Sailing Directions

The 14th edition of *B.C. Sailing Directions, Volume I (South Portion)* was published in June, and an 11th edition of *Volume II (North Portion)* in December. New photographs were taken for the next edition of the *Great Slave and Mackenzie River Sailing Directions*, and for revisions, a cruise of the B.C. coast, concentrating on the islands and inlets adjacent to the east side of Queen Charlotte Sound and Hecate Strait was undertaken.

The text for the *Mariner's Routing Guide for Juan de Fuca Strait and Southern Strait of Georgia* was prepared. *(Contacts: A. Smith, G.E. Richardson, L.M. Chan.)*

Marine Cartography

The Chart Production and Distribution Section ensures that survey and all other pertinent data are processed for publication and keeps an up-to-date supply of all charts and publications available for distribution.

A major accomplishment during the year was the release, in May, of New Edition Chart 3311 for the Sunshine Coast. For use on small craft, #3311 consists of five charts in strip format. Its production involved the updating of digital chart files, the first time this process has been used extensively in the production of a New Edition.

Chart #	New Charts Produced in 1987/88
3424	Approaches to/Approches à Oak Bay
3564	Plans - Johnstone Strait
3909	Plans - Chatham Sound
3956	Malacca Passage to/à Bell Passage
3957	Approaches to/Approches à Prince Rupert Harbour
3959	Hudson Bay Passage
6452	Mackenzie River/Fleuve Mackenzie (0-58 km)
6453	Mackenzie River/Fleuve Mackenzie (58-90 km)
6454	Mackenzie River/Fleuve Mackenzie (90-147 km)
6455	Mackenzie River/Fleuve Mackenzie (147-205 km)

Twenty-one New Edition charts were produced as were twenty-five Reprints, thirteen overprints, two chart patches, and one reprint.

The Hydrographic Data Centre processed 812 plans, 341 MAREP forms (from the Canadian Power Squadron's Marine Reporting), and fulfilled 149 survey document requests.

There were 109 Notices to Mariners and 11 Notices to Shipping issued, as well as 86 Navigational Aids Copies, and 25 Nomenclature Copies. The Navigational Aids Section reorganized all nomenclature file cards (approximately 10,000) to conform with the system in current gazeteers. Almost 200 survey positions of Pacific Coast Lights were prepared for inclusion in Nautical Geodesy's Lites File.

Further production included a second reprint of the Juan de Fuca Strait to Strait of Georgia Current Atlas, and a New Edition of Chart 3670 of the Pacific Rim National Park. This chart, a cooperative venture with Environment Canada's Parks Branch, contains parks information on the reverse side.

In addition to continued involvement with Chart Production, the Photomechanical Unit also provided support to other sections of the Institute of Ocean Sciences, producing 6500 contact exposures, 1600 camera exposures, 140 scribe etches, and 97 colour photos.

Revenue received from chart and publication sales totalled over $736,000. The Chart Sales Office distributed 140,976 charts, 64,690 publications, and 18,673 free brochures. There were 19 dealer inspections.

A display including new Chart 3552 and panels describing the symbols and abbreviations portrayed in Chart No. 1 was assembled by staff for the Vancouver Boat Show.

Accounting and inventory software were rewritten and itemized invoices are now included with each order. A VT320 terminal and LA 2210 printer were acquired. These were connected to the VAX 750 Chart Production Computer.

Chart Amendment staff applied corrections to 147,761 charts and one and a half million amendments were applied. In addition, staff assisted in designing the Vancouver Boat Show display.

Chart Production staff were also involved in continuing production of a new cruising atlas of the Gulf Islands and a *Mariner's Routing Guide for the Juan de Fuca Strait and Southern Strait of Georgia.*

Activities in Computer-Assisted Cartography continued to place a heavy demand on existing facilities. Scheduling periodically required two shifts for digitizing and editing. A DEC RA81 disc drive has been installed allowing an additional 460 megabytes of storage. The digital library was transferred from the SPERRY to the VAX 750 and is now on the new RA81. Two VT320 terminals replaced the VT52 terminals. ETHERnet and DECnet were installed for communication links with Computing Services' VAX 785. DECnet also allows CHARTS software to run on the Tektronix 4224. One Tektronix 4111 and one USL controller for the ALTEC digitizing table have also been acquired. The Tektronix 4125 was upgraded from 16 to 64 colours, and software for the VAX 750 version of VMS has been upgraded to 4.7.

A contract for digitizing nine hydrographic field sheets of various sizes and scales, was awarded in February 1988. Assessment of the digital date is yet to be completed.

Promotional activities in 1987/88 were limited to the Vancouver Boat Show. However, tours and lectures for the Canadian Power and Sail Squadron, Malaysian and New Zealand Navy representatives, local government officials and yacht club members continued to be extremely popular.

Five cartographers attended CHS Cartography courses in Ottawa, two completing Cartography I and three completing Cartography II. A unit supervisor rotated through Quality Control on an extended basis to fill the temporary void left by the retirement of Austin Ross. One cartographer spent eight weeks on rotational assignment with NOS in Seattle, Washington and Rockville, Maryland. Another participated in an extended field assignment with the Vancouver Harbour survey

party. A unit supervisor and a quality control officer attended a Senior Cartographers' seminar in Ottawa.

The Hydrographic Data Centre set up a database system indexing approximately 1500 field sheets. Initial input was performed using contract personnel and two students, one from South America, under a World Youth Organization exchange program.

Tidal and Current Surveys

Pacific Region of the Canadian Hydrographic Service conducts or arranges, the maintenance of 21 permanent and four temporary tide gauging stations on the Pacific Coast and in the Western Arctic.

Data from these gauges is processed and archived monthly, and used for studies of mean sea level (i.e. IGOSS Sea Level Pilot Project), crustal movements and storm surges, as well as for hydrographic surveys, oceanographic studies, and the Tide and Current Tables.

The region also operates and maintains two tsunami warning stations on the Pacific Coast. A prototype station using Meteor Burst mode for data transmission was operated at Queen Charlotte, telemetering data to Victoria once an hour, or whenever a rapid rise or fall in water level was detected. Two additional Meteor Burst mode stations will be built on the outer coast in 1988. These will improve the reliability and speed of Canada's share of the Pacific Tsunami Warning Network. *(Contact: F.E. Stephenson.)*

Surveys of currents in hazardous and fast flowing narrow passes on the British Columbia coast are continuing and proceeding on schedule. Current surveys of passes in the Stuart Island area (Whirlpool, Greene, and Arran Rapids), as well as surveys in Sulphur Passage and Seymour Narrows were carried out. Currents were measured during a complete spring and neap tidal cycle. A short current survey of Hayden Passage was conducted by a PENDER hydrographic field party. A prototype digital current meter, developed at IOS, was tested and found to perform well in its first field application.

All CODE data obtained from 1979 to 1981 have been published and are available to the public. Loran C drifting buoys were deployed on two cruises of CSS PARIZEAU, to measure surface current rates and direction. Data will be used for navigational information and to support projects at the Pacific Biological Station. *(Contact: M.J. Woodward.)*

The intensive field work by the Ocean Storms program ended in November 1987

and the last moorings were recovered in June 1988. Before the explosive storms of the north east Pacific can be modelled successfully, the rate of heat transfer between ocean surface, deep ocean and the atmosphere must be understood. In the autumn of 1987, 30 Canadian and American scientists examined this heat transfer using airplanes, moored instruments, ships and ocean drifters for several months. Results are being processed, and over the next few years, the predictive models will include the new physics of these storms. *(Contact: W.R. Crawford.)*

Previous studies with moored current meters showed a northward Vancouver Island Coastal Current near the west coast of the island, and in summer a southward flowing current near the shelf break. Recent studies using Loran C drifters have found that the Tully Eddy off the mouth of Juan de Fuca Strait "holds water", but not as well as expected. The flow on La Perouse Bank was found to be much slower than in surrounding waters, and the Vancouver Island Coastal Current sometimes squirts away from the coast just south of La Perouse Bank. These drifter studies will continue as part of MASS to determine if other preferred sites of these offshore flows exist along the island. *(Contact: W.R. Crawford.)*

A computer model was developed to study the effect of a proposed training wall in Annacis Channel on the stability of the waterway (part of the trifurcation near New Westminster). Model and field observations to verify results were completed in December 1987.

Time-series were continued in the seaward reaches of the Fraser River to measure currents near the interface of an advancing salinity wedge.

A computer-graphic film was produced to simulate the movement of a pollutant in the Fraser Estuary, and to show how it is affected by the interaction of tides and river discharges.

A technique has been modified which allows oilspills to be tracked from the air during periods of poor visibility. It makes use of floating transmitters by replacing the previous Inertial Navigation System with a portable Loran C inside the aircraft. The new navigation system was successfully tested and, at the request of Environment Canada, applied to inspect an offshore gypsum dump site. *(Contact: A.B. Ages.)*

Diving Unit

The Diving Unit consists of thirteen divers–nine in Hydrography, two in Ocean Physics, and two in Ocean Chemistry. They carry out diving activities on a part time basis in support of IOS programs.

In 1987-88, 162 dives were made, resulting in a combined underwater time of 79.2 hours. The majority of dives supported tide and current surveys. Bottom mounted pressure gauges on the Pacific coast and in the Western Arctic were deployed or recovered, and current meters were serviced at several locations in the waterways between Johnstone Strait and the Strait of Georgia. A number of dives were also made at permanent tide gauge sites to clean staffs and orifices, replace zincs, and repair or note the condition of the underwater structures.

At Patricia Bay, chemistry enclosure experiments were supported, and the deployment and release of a prototype mooring was observed for Ocean Physics. Divers also assisted in recovering many jetty fenders.

An increase in Marine Division activity has meant an increase in requests for diver support. Divers conducted underwater inspections of the PARIZEAU and TULLY, and four other vessels received at least one inspection.

A training program was organized and carried out, in addition to annual medicals and CPR training.

All activities are carried out in accordance with the Departmental Guide for Diving Safety, supplemented by regional guidelines. A new set of diving regulations is being prepared and is expected to be approved and completed in 1988.
(Contact: F.E. Stephenson.)

Engineering Services

The group provides electronic and mechanical engineering and electronics support for hydrographic surveys, oceanographic research, and marine operations. Industrial liaison also operates from within the group, promoting the established Contracting Out policy and interaction of IOS with other government departments and the private sector. *(Contact: T.A. Curran.)*

Institute Electronics

Activities which included the repair, calibration, and routine maintenance of equipment in support of hydrographic field and oceanographic programs and marine operations were successfully performed during the year. The major equipment areas were radios, depth sounders and digitizers, positioning systems, and ruggedized launch computers.

The group now services all Trisponder systems for IOS and the Pacific Geoscience Centre. The ability to transfer facsimile images over HF radio to ships at sea is now standard. Significant effort was devoted to maintenance of the cartographic draughting system.

In support of hydrographic field operations, personnel supported barges PENDER and L. PACIFICA and prepared three ships and ten launches for the 1988 season.

Assistance to the private sector included an evaluation of the frequency stability of an EPIRB under development and numerous requests from small companies. The group acted as scientific authority on upgrades to the HAL launch computer.

The group has undertaken system responsibility for the environmental data loop on the major scientific vessels -- Serial ASCII Interface Loop (SAIL).

Development effort included design of an antenna switching unit for Trisponder positioning systems and an evaluation and report on the performance of amorphous silicon solar panels. *(Contact: E.W. Hinds.)*

SAIL has been been transferred to the Institute Electronics group for ongoing maintenance. The group's work included hardware debugging during the year. A new version of the logging software, in C language, was developed under contract and tested during several cruises. It is planned to implement a SAIL archiving system in 1988, including production of monthly data reports.

There were considerable small but important engineering jobs performed by the group. Of note is the work of the Precision Machine Shop. *(Contact: J.L. Galloway.)*

Engineering Development

Engineering Development provides custom development of hydrographic and oceanographic instrument systems, and a consulting service to IOS.

The main mechanical activity was contract supervision of the remotely-operated vehicle (ROV), with a design capability to operate at 5000 metre depths. The development efforts culminated in March 1988, when demonstration dives in Halifax Harbour and deepwater tests off Bermuda were performed. Problems with the fibre optic data telemetry were discovered. Further cable tests are planned with International Submarine Engineering (ISE) and the cable manufacturer, Rochester. The sample tray, suction sampler and other scientific instruments from the PISCES were modified to work with the ROV. Presentations were given at Oceans 87 in Halifax and IEEE in Victoria.

A narrowbeam Acoustic Telemetry System, jointly developed with Royal Roads, was transferred to ISE for evaluation as a possible communication method for autonomous submersibles. Two papers were presented on the technique. An acoustics research project for MASS was conducted to detect juvenile salmon in Barkley Sound using sidescan in a vertical orientation and profiling mode. Development and field tests are continuing. The correlation sonar system will be deployed in 1988 in the Beaufort Sea to measure ice motion. There were several internal requests for acoustic transducer beam pattern and response tests, as well as requests from other research institutes and industry. Three engineers from IOS attended a graduate acoustics course at University of Victoria. Recognition of the interdisciplinary and fundamental nature of ocean acoustics, and its significance to DFO, was achieved through strong representation by IOS at a major workshop at the Bedford Institute.

Facsimile telemetry of images to ships at sea was successful, and is in use by the Ocean Ecology group. The main limiting factor is the sparsity of useful imagery to telemeter because of cloud limitations, rather than the technique itself. A paper was submitted for journal publication.

Physical and Chemical Sciences

Ocean Physics

The scientific program of the Ocean Physics Division covers a wide range of topics, reflecting the diverse geography and ocean activity on the Pacific and Arctic coasts. During the period covered by this report, emphasis was on improving the description and understanding of ocean conditions on the Pacific and Beaufort Sea continental shelves, and on application of the resulting information to the prediction of fish stock recruitment and ice motion. Other areas of special attention included theoretical studies directed towards improving modelling of large scale ocean circulation in preparation for planned international experiments, development of new observational tools using acoustic techniques and the improvement of weather and sea-state forecasting on the Pacific coast in cooperation with the Department of the Environment and the Ministry of Transport.

Fjords and Narrow Channels

The year-long field measurement program in Neroutsos Inlet completed in the fall of 1987, was part of an oceanographic study intended to identify the dominant physical processes affecting the upper layers of this fjord which shows severely depressed dissolved oxygen content due to pulp mill discharge . Analysis of this data has identified local winds as the primary forcing for the currents in the upper 25 metres. The currents are believed to play the dominant role in replenishing the dissolved oxygen content of the fjord and in dispersing the pulp mill effluent. A dissolved oxygen budget analysis of the upper 25 m of the fjord is underway with objectives to determine major sources and sinks of dissolved oxygen, time scale of fluctuations, and the problems involved in estimation. *(Contact: D. Stucchi.)*

Using CTD (conductivity-temperature-depth) data gathered over the last decade by IOS on B.C. fjords, vertical eddy diffusivities Kv(z) for the deep waters of five fjords were computed using the budget method outlined by Gargett (1984). In two fjords, double diffusive conditions were present. Vertical eddy diffusivities varied widely but were smallest in Saanich Inlet and largest in Knight and Observatory inlets. The eddy diffusivity for heat was not found to be significantly higher than that for salt. *(Contact: D. Stucchi.)*

Analysis of an extensive set of data from two cruises to the Strait of Gibraltar was completed. Observations include current measurements from a moored array, and Doppler profiles from a ship, together with XBT deployments and high frequency echo-soundings. The analysis demonstrated that the exchange flow was maximally controlled in the hydraulic sense. Two layer hydraulic theory has been shown to provide a consistent basis for interpreting the results, and accounts for several features of the exchange flow, including the periodic tidal flooding of the sill control at Camarimal, the release of an internal bore and the presence of supercritical jet in the eastern part of the Strait. *(Contact: D.M. Farmer.)*

Continental Shelves

A major emphasis in the physical oceanography program is on continental shelves. This is a reflection of Canada's responsibility for management of the area and of the role which scientific knowledge may play in boundary and sovereignty issues.

In April and May an array of current meter moorings was installed in a triangular pattern at 20 m off Cape Bathurst in the Beaufort Sea. Each mooring contained seven metres to measure the response of water columns to forcing events under conditions where the under-ice and benthic boundary layers merge. One such event was recorded during the six-week deployment period. *(Contact: D.R. Topham.)*

In late March, a CTD and chemistry survey of the Beaufort Sea was carried out. In this fourth year of a planned five-year sequence, shelf-water salinity was high, as in 1981, but not in intervening years, despite below-normal ice growth. The water-chemistry data suggest that strong upwelling in the fall of 1987 is responsible for a significant portion of the seasonal salinity increase. Cold shelf waters of enhanced salinity ventilate the upper portions of the Arctic in some winters, and thereby isolate the ice cover from warmer underlying waters of Atlantic origin. *(Contacts: H. Melling and R.M. Miller.)*

A study of the mesoscale (5-50 km) flow structure over the Mackenzie shelf was conducted in August and September. Eleven drifters were used, all equipped to measure sea surface temperature, and four equipped to measure temperature profiles down to 20 m. The drifters were drogued at 2.5 m and 17.5 m. The shallower depth corresponded to that of oceanic water freshened by melt and river inflow. This layer most strongly affects the drift of sea ice. The different trajectories observed at the two depths provide a measure of the suitability of the barotropic-ocean-model predictions for ice-drift prediction in this area. *(Contact: H. Melling.)*

An extensive series of laboratory experiments has been performed to measure the

drag of ice keel models when towed in two-layer stratified water conditions. The entire Froude number range, from subcritical through to supercritical, has been investigated for a keel depth to upper layer depth ratio of 0.5. Force measurements and detailed flow patterns have been obtained throughout this range. *(Contacts: D.R. Topham and H.D. Pite.)*

A comparison of computed and observed sea levels and currents was undertaken for the storm of September 1985 in the Beaufort Sea. Computed values were generally in good agreement with sea levels and depth-averaged currents observed during the PERD observational study of 1985/86. Following the passage of a storm however, the relaxation of the sea-level and circulation fields was accomplished through the radiation of energy by shelf waves, and through scattering into high mode components. These are unlikely to be predictable by deterministic means. *(Contact: W.P. Budgell.)*

Numerical simulations of remotely forced, coastally-trapped waves in the Beaufort Sea suggest that the Canadian portion of the Beaufort shelf is decoupled from the Alaskan portion. Incident shelf waves propagate further east. In this series of simulations, no scattering of shelf waves into smaller scales was observed. This, and preliminary comparison with observations, suggest that for circulation modelling, attention can be restricted to the Canadian shelf. *(Contact: W.P. Budgell.)*

Research was conducted on a wide variety of problems involving mesoscale oceanic variability off the B.C. coast. Analysis of field observations consisting of current meter measurements, water property data, satellite-tracked drifter records and satellite thermal imagery were combined with numerical simulation models to verify that the quasi-permanent 50 km scale eddy off the southwest tip of Moresby Island arises from rectification of the regional tidal currents.

Available current and water property data were used to provide a detailed description of the seasonal circulation patterns off the west coast of Vancouver Island with particular emphasis on the poleward-flowing, buoyancy-driven Vancouver Island Coastal Current. An attempt was made to link the flow structure to fish distribution and recruitment along the southwest coast. Data collected in 1984 during the joint Canada-U.S. Vancouver Island Coastal Current Experiment were used to investigate possible non-linear interactions between high frequency internal waves and mean currents over the continental shelf.

The long-term fisheries-oceanography monitoring programs--La Perouse and Marine Survival of Salmon (MASS) projects--were continued over the southwest shelf region. In addition to maintaining three moorings, a total of 14 oceanographic surveys were conducted in support of fisheries research. Work began on the dynamics of the spring and fall transitions along the coasts of Vancouver Island and the Queen Charlotte Islands. *(Contact: R.E. Thomson.)*

A CTD survey was conducted from the Canadian ice island off the coast of Axel Heiberg Island (approximately 81°N). The line of stations over the 400 metre-deep continental shelf indicated the existence of an unexpectedly strong geostrophic shear at the shelf break where the depths increase sharply to 3000 m. This feature was co-incident with a frontal zone separating offshore water and shelf water which is somewhat modified by vertical mixing. Surface salinities on the shelf were significantly higher than offshelf and higher than in previous years in spite of very intense summer melting--one metre of ice was lost from the surface of the ice island. Further studies are planned to provide direct measurement of current in order to verify the conclusions. *(Contact: R. Perkin.)*

An analysis of the vorticity budget in a localized region of the B.C. continental shelf showed that the dominant terms in the dynamical balance are the two non-linear terms. These, though larger, almost perfectly correlate so that the sum (the Jacobian of vorticity with stream function) is small. This implies that a linear model of the large Rossby number-flows on the continental shelf may have surprisingly good validity. The analysis also demonstrated that the Tully Eddy (a large cyclonic circulation north of Juan de Fuca Strait) is driven by upwelling from the head of a small canyon. *(Contact: H.J. Freeland.)*

A statistical dynamical theory was developed to show how eddies on the continental margin, interacting with longshore variations in bottom topography, produce a systematic force which drives coastal undercurrents. The effect also extends to driving a systematic upwelling tendency, bearing upon the nutrient burden and productivity of the shelf region. The theoretical model was examined and compared with numerical simulation results. *(Contact: G. Holloway.)*

Climate Studies and Deep Sea Oceanography

Fluctuations of sea level were combined with global ocean atlas data to estimate eddy transports of heat and freshwater; first for the north Pacific and then for the entire southern hemisphere. In the southern hemisphere, the calculation showed how oceanic heat is transported toward Antarctica before escaping to the atmosphere. Further applications are being explored in cooperation with scientists at the NASA Jet Propulsion Lab. *(Contact: G. Holloway)*

Three ocean-climate monitoring cruises to Ocean Station P (50°N, 145°W) and associated lines were made during 1987, primarily to collect temperature-salinity-oxygen data. Two cruises were made to support the Ocean Storms project. *(Contact: S. Tabata.)*

An RD Instruments Acoustic Doppler Current Meter was used for the first time to

measure the backscatter intensity and three-dimensional current structure associated with a mid-ocean ridge hydrothermal plume. These observations, conducted during September, marked the end of the three-year field program with Oregon State University to investigate the physical and chemical oceanic properties in the vicinity of the Endeavour segment of Juan de Fuca Ridge. *(Contact: R.E. Thomson.)*

Twenty-four deep-drogued, satellite-tracked drifters were deployed in the northeast Pacific Ocean in June and October as part of a joint research program with the universities of Alaska and British Columbia to monitor the structure and variability of the Gulf of Alaska circulation at depths of 100 to 150 metres. The study also includes the deployment of two deep-sea current metre moorings to monitor the long-term changes in absolute flow structure during the two years of the experiment. *(Contact: R.E. Thomson.)*

The sensitivity of large-scale ocean models to different representations of small-scale mixing has been examined in context of the Geophysical Fluid Dynamics Lab ocean model. *(Contacts: G. Holloway and P. Cummins.)*

An analysis of linear trends in steric sea level obtained from the 27-year hydrographic record from Station P (50°N, 145°W) indicates that sea levels in the northeast Pacific are rising at approximately one millimetre per year relative to the 1000 m reference level and that 67 per cent of this change is due to thermal expansion at depths below the 100-metre deep surface layer. Dilution of the surface layer is also contributing to the trend. The results are consistent with possible climate-induced/induced sea level rise due to increased concentrations of "greenhouse" gases in the atmosphere. At present, the trend is of marginal statistical significance. Another decade of observations may be required before complete confidence in the observed trend can be established.
(Contacts: R.E. Thomson and S. Tabata.)

Upper Layer Processes

A series of laboratory grid-stirring experiments with two layer systems, stratified by both heat and salt, showed that heat and salt are not necessarily transferred at the same rate, with implications for turbulent transfers in the ocean.
(Contact: A.E. Gargett.)

A new "large-eddy" approach, using acoustic Doppler profiling techniques, has been applied for remote sensing of turbulence kinetic energy and its dissipation rate (E). Preliminary comparison of E values is encouraging. *(Contact: A.E. Gargett.)*

In support of climate research, work continues on the parametric representation of

sub-gridscale processes for large-scale ocean models. Both statistical dynamical theory and detailed numerical modelling are being used. One of the more unusual results is the demonstration of how internal gravity wave "breaking" can sustain a mean counter-gradient buoyancy flux. Eddy representation on a larger scale, "anticipated vorticity," has been re-examined to find that the numerical implementation of this method can be more than 1000 per cent more efficient.

A new numerical hydrodynamical technique was developed in order that fluid flow past irregularly shaped boundaries can be treated with the accuracy and efficiency of spectral transform methods as compared with more traditional finite difference or element methods. Applications have begun with respect to internal gravity waves encountering sea-floor topography. *(Contact: G. Holloway.)*

Forecast Development

A major review paper summarizing all numerical models developed by IOS for the Strait of Georgia, Juan de Fuca Strait and the Puget Sound has been accepted for publication in the journal, *Oceanography and Marine Biology: An Annual Review.* Discussions were initiated in Hamburg, Germany on Phase II of the Canada-Germany collaboration on developing advanced three-dimensional models for the straits of Georgia and Juan de Fuca. *(Contact: T.S. Murty.)*

A contract with SeaConsult Marine Research Ltd. of Vancouver, on the evaluation of potential tsunami levels for the Pacific coast was completed. Collaboration with the U.S. on evaluating tsunami threat to the Pacific northwest region of North America is continuing. *(Contact: T.S. Murty.)*

The development of a finite element barotropic tidal model of the southwest coast of Vancouver Island for the MASS project was undertaken and its results compared with both observations and other numerical models. In conjunction with Oregon State University, work was also begun on the development of a 3-D thermocline model of the north Pacific Ocean. *(Contact: M.G. Foreman.)*

As part of a joint program with DOE and MOT, two large meteorological buoys were installed at the outer limit of the Canadian Economic Zone, and a network of coastal wave buoys was maintained. A study of the significance of interactions between waves and tidal currents was completed by Pacific Ocean Sciences Ltd., showing this effect to be important for many areas on the B.C. coast. A feasibility test of running wave models locally has been started under the control of the operational meteorological forecaster. *(Contact: J. Garrett.)*

Observational Techniques

A fibre optic, fluorescence-based, dissolved oxygen sensor developed in conjunction with Seastar Instruments, was deployed at a depth of 100 m for six days in Saanich Inlet. The instrument has a response of less than 10 seconds and is capable of resolvent variations of less than 0.1 mg/l. Results provided the first time series measurements of the variability high frequency oxygen from a moored site. Observations proved long-term stability and accuracy of the instrument in the moored mode and will assist in the development of a commercial sensor for general oceanic application. *(Contacts: R.E. Thomson and T.A. Curran.)*

Sea-I Industries was contracted to produce a modified version of its Manta-II Remotely Operated Vehicle for a stable, rapidly towable oceanographic platform for use in northeast Pacific surveys to depths of up to 2500 m. Specific applications include synoptic surveys of hydrothermal vent regions and deep-sea turbulence measurements. *(Contacts: R.E. Thomson and T.A. Curran.)*

A study was undertaken to explain the stages of ice-cracking and break-up, and to determine the acoustic signatures of various cracking events. New acoustic methods of observations were used in the study. Ambient sound was recorded in Amundsen Gulf at six frequencies between 50 and 14,500 Hz from April to August, and was supplemented with a broad-band (20 to 22 k Hz) recording from a three-dimensional array of hydrophones beneath the ice in 1987. The broad-band measurements have been interpreted in terms of a theoretical model of cracking that is related to models of earthquake mechanics. *(Contact: D.M. Farmer.)*

An experiment was carried out as part of the Ocean Storms program to study turbulence in the upper ocean boundary layer. Using a new system to suspend an instrument package in the relatively quiet environment at a 30 to 35-metre depth, observations of surface waves and bubble clouds were used to trace coherent features of the turbulence in the water above. Sidescan images show the organization of bubble clouds into long horizontal columns aligned approximately with the wind. Multiple frequency echo-sounder and Doppler measurements allow delineation of bubble size distribution and vertical velocities. Clear indication of Langmuir circulation was obtained and the results will be used to test various generation models for this type of circulation. On a similar front, ambient sound measurements from several locations have been used to probe the breaking of the surface waves. Results show that with appropriate signal analysis, the wave period, group structure, mean density of breakers and the acoustic strength of the breaking events can be determined. Subtle influences of the bubble clouds on the acoustic signature have been identified and analytical techniques developed to use the structure of ambient sound to prove their distribution and behaviour.
(Contact: D.M. Farmer.)

Techniques are being developed for the study of flow structure and turbulence using acoustic scintillation. Sound travelling through an inhomogeneous medium accumulates variability from the structure of the flow through which it passes; scintillation analysis concerns the extraction of useful information from the resulting signal. Two-dimensional arrays deployed in Cordova Channel have been used to acquire data that allows analysis of the turbulent structure of the flow; spatial aperture filtering has been successfully applied to profile properties along the acoustic path. *(Contact: D.M. Farmer.)*

The FLI (Fluorescence Line Imager) was flown over Barkley Sound as part of the MASS project. Imagery showed the distribution of solar induced fluorescence from near surface chlorophyll. Observed fluorescence correlated well with simultaneous surface measurements of chlorophyll concentrations.

To test the correlation between solar-induced fluorescence that can be measured with the FLI and phytoplankton productivity, water-leaving radiance spectra were collected during a two-week PARIZEAU cruise off the west coast of Vancouver Island. Further work is planned on this problem as part of a cooperative research program with Germany (FRG).

Imagery of Barkley Sound was also produced from thermal and visible data provided by the Thematic Mapper on the Landsat satellites, and by an airborne Daedalus scanner. These showed thermal patterns, but lacked the sensitivity and spectral resolution to map phytoplankton.

GEOSAT altimetry data was evaluated for its potential to monitor mesoscale ocean dynamics in the northeast Pacific. Software was written to reduce satellite tracking errors by minimizing cross-over differences. This will be used to produce monthly composites of sea surface height anomalies. *(Contact: J.F. Gower.)*

Ocean Chemistry

During 1987/88 Ocean Chemistry was involved in both applied and targetted basic research on chemical aspects of ocean environment. Emphasis was focused on climate, arctic and pollution-related research.

Targetted basic research was concentrated on the oceanic modulation of the atmospheric burden of carbon dioxide (CO_2) and other "greenhouse" gases. The long-term focus is on the oceanic capacity to absorb these gases, and the secular increase of CO_2 in both the atmosphere and the ocean. However, the major effort in 1987/88 was devoted to documenting the ocean changes associated with the El Niño, which extended from late 1986 to the end of 1987. Another major effort was on understanding how efficient the natural "biological pump" has been working in the north east Pacific Ocean as a means to sequester CO_2 in the upper ocean by photosynthesis and interactions of the marine food chain as a means of moving detritus carbon into deep-water storage. The global air temperature, 0.33°C higher in the 1980s compared to the 1970s, could have changed the oceanic "biological pump" in a major way. Records at Station P show a possible increase in productivity in the 1980s compared to historical data.

The Beaufort Sea chemical oceanography project, supported by the Northern Oil and Gas Action Program (NOGAP), completed a very successful field program on ice and in open water. Time-series observations of seasonal changes in hydrocarbons, sea water chemistry, detritus fluxes and production were carried out. Sediment-oil interaction was investigated.

In the area of contaminant chemistry, a study of the levels of metals and chlorinated organics in sockeye salmon in the Fraser River was carried out. Chlorophenols, DDTs, PCBs and chloroguiaicols were studied near outfalls and pulp mills. Mine tailings discharged in inlets were studied and a project on arsenic in Alice Arm and other fjords was completed. A cooperative project between Canada and China, and funded by the International Development Research Centre (IDRC) was successfully completed. The project ended with an international symposium, in Beijing, on Marine Ecosystem Enclosure Experiments.

Centre for Ocean Climate Chemistry

CO_2 and other Climatic Gases

The Centre for Ocean Climate Chemistry has been designated a Centre of Disciplinary Expertise (CODE) for targetted basic research into the oceanic modulation of atmospheric CO_2 burden and other greenhouse gases. A monitoring strategy was adopted to quantify the oceanic modulation of atmospheric greenhouse gases by biogeochemical processes and ocean circulation. It was an exciting year to record ocean chemical changes, one that offered an unparalleled opportunity to take a close look at an extended El Niño in the central Pacific Ocean. Sampling for nutrients and other chemical oceanographic properties was conducted from the M.V. LILLOOET, a container ship travelling between Brisbane, Australia and Richmond, B.C. A dramatic drop in nitrate, first observed in December 1986, increased in the equatorial waters in March and May with the return of upwelling around the equator. However, in the second part of the year, data indicated almost zero levels of nitrate in the upper ocean between 25°S and 35°N, indicating an extended El Niño. Shipboard instrument also measured the partial pressure of CO_2 (pCO_2) between the atmosphere and the ocean. The evasion of CO_2 from the equatorial waters of 5°N to 5°S into the atmosphere decreased drastically during the spring of 1987 to almost zero in the fall, as a result of the surface warming preventing deeper CO_2 and nutrient-rich water from upwelling.

The standards laboratory for CO_2 and other gases has yielded good agreement with the Global Monitoring for Climatic Change (GMCC) exercises carried out under the auspices of the National Oceanic and Atmospheric Adminstration (NOAA) at Boulder, Colorado. NOAA standards, traceable to the WMO calibration scale, were intercalibrated at the COCC laboratory with a special cathetometer, now improved to a precision of +0.03%; precision required for monitoring global secular CO_2 increase and for the study of long-term amplitude change in the global CO_2 records due to change in photosynthesis and respiration. The Centre was also involved in the Joint Panel on Oceanographic Tables and Standards (JPOTS) Scientific Committee on Oceanic Research (SCOR) intercalibration of oceanic reference sea water. In preparation for this intercalibration and the PERD CO_2 funding, development was done on a coulometric method for CO_2 measurement and gas chromatographic method for pCO_2 of preserved samples. *(Contact: C.S. Wong.)*

Ocean Flux

Two main issues were addressed in 1987/88: global change in productivity of the ocean, and the efficiency of the natural sedimentation process in removing CO_2 from the upper ocean into deep-water storage. At Station P, primary productivity was determined by a metal-free C-14 tracer technique and by measuring the carbon uptake in incubated light and dark bottles suspended from a free-floating array at 10 m intervals to a depth of 100 m. Results between 1984 and 1988 showed higher productivity than the historical dataset of the 1960s. Station P, one of the few sediment trap flux monitoring stations in the world, has also been the site of time-series studies since 1982. Fluxes in surface and intermediate waters (to 1000 m) were measured by using a string of sediment traps, 100 m apart, set adrift for two to four days and located by a satellite-positioned ARGOS buoy. Deep water fluxes of materials were studied using moored, automated sequential sediment traps. Samples of detritus were collected biweekly at 1000 m and 3800 m at Station P, and 500 m at Station P3 (48.5°N, 126.5°W) for periods up to six months. Very marked seasonal and interannual variabilities for the flux of materials were observed. Organic carbon, organic nitrogen, carbonate and opal fluxes were determined. The mercury flux was found to be almost equal to the atmospheric mercury flux input into the ocean. Peak flux of material for Station P3 indicated a winter maximum, possibly from terrestrial input. The program will be part of the Pacific Joint Global Ocean Flux Study (JGOFS) now being organized for the north Pacific countries. *(Contact: C.S. Wong.)*

Contaminant Chemistry

The program studied the levels, effects and pathways of chlorinated hydrocarbons, metals and petroleum hydrocarbons in marine organisms, fish and waters of the B.C. coast and rivers. Program activity involves IOS and West Vancouver Laboratory staff.

The project on chlorinated hydrocarbons conducted in the Fraser River system, examined the body burdens of toxic chemicals in fish. Chlorophenols, DDTs and PCBs were measured in starry flounders, collected near a large municipal outfall at the mouth of the north arm of the Fraser. Mussel tissues were found to have maximum chlorophenol levels at about one half of the Canadian limit, one tenth the PCB limit established for edible fish tissue. With the exception of DDD which was greater in the reference area, comparison of matched tissue samples from the polluted zone and the adjacent reference area, showed statistically significant higher levels of all target compounds in muscle tissue from the outfall areas. Bone and liver tissues were enriched in PCBs and DDTs. Another component of the project studied

juvenile chinook salmon overwintering in the upper Fraser River between Prince George and Quesnel. The fish survived exposure to treated pulp mill wastes and municipal sewage in water at 0.5° C under shore ice while residing in areas of cobbles. Comparison of bodyburdens of chlorophenols and chloroguiaicols in fish taken in November 1986 with those in fish sampled in March 1987 showed statistically higher levels of five of six target compounds, after the winter exposure. The compounds 3,4,5-trichloroguiaicol and tetra-chloroguiaicol residues of pulp bleaching were mostly concentrated in the river water and in the fish. *(Contact: I.H. Rogers.)*

A four-year study of arsenic in interstitial waters from the sediments of two B.C. coastal fjords was completed. The study centred around the hypothesis that arsenic contained in mine tailings discharged to the inlets may result in an increased availability of the element through conversion to organic derivatives. For the first time, quantifiable amounts of three organoarsenic moieties were found in the porewaters from marine sediments of both natural areas and that disturbed by discharge. In Alice Arm, arsenic flux was negative for the deposited tailings. A new analytical method with improved recovery was applied to assay trace metals in porewaters on inlet floors with mine tailings deposit. Using electron microscopy and energy dispersive X-ray spectroscopy, another metal project was conducted on trace metals in tissue compartments of the Golden King Crab, *Lithodes aequispina* Benedict. Lead and other sulfide-bound elements were found to be in chemically-bound form at the gill surface, rather than occluded particulates. *(Contact: J.A.J. Thompson.)*

IOS Ocean Chemistry participation in the Baffin Island Oil Spill (BIOS) project was published in a special issue of ARCTIC. Various aspects of the study such as biodegradation, fate of chemically dispersed oil, effects of sediment on the biogeochemistry of oil degradation and description of the BIOS experiment were published. *(Contact: W.J. Cretney.)*

An enclosure experiment, part of a cooperative study with Japan, was conducted on the transfer of metals and organics in sea water. The experiment was carried out at Patricia Bay with the participation of scientists from Nagoya University and the University of Tokyo, and with chemists from IOS. An international symposium on Marine Ecosystem Enclosure Experiment was held in Beijing, China in May 1987 to mark the completion of a three-year cooperative project between Canada and China. The project, on the application of the enclosure technique to study the pathways and fate of pollutants in the marine environment and their biological effects, was funded by IDRC. The experiments were conducted at the Third Oceanographic Institute in Xiamen, China and at IOS. Forty-four papers were included in the abstract volume of the symposium. Participants at the symposium were from Canada, China, U.S.A., F.R. Germany, Netherlands, Norway, U.K. and Hong Kong. Proceedings will be published by IDRC. *(Contact: C.S. Wong.)*

Beaufort Sea Oceanography

The Northern Oil and Gas Action Program (NOGAP), funded by the Department of Indian and Northern Affairs, involves two territorial governments and seven federal departments. The goal of the program is to prepare government for major hydrocarbon development north of 60°. A sub-project of NOGAP, Beaufort Sea Oceanography commenced at IOS in 1986. In the second year of operation, the sub-project emphasized field collection of data in support of program objectives to measure primary productivity, its timing and magnitude; and to determine natural hydrocarbon sources, sinks, and pathways for the Mackenzie River estuary and Beaufort Sea shelf.

Central to IOS field work was the maintenance of a time-series transect of physical, chemical and biological properties across the centre of the Beaufort shelf. The transect followed the season as it unfolded from winter (low productivity, low terrestrial inputs, brine injection) to summer (higher productivity, peak inputs from the Mackenzie River, fresh water injection). This was initially accomplished from a base in Tuktoyaktuk (PCSP) with aircraft logistical support to work on the ice until breakup. After breakup the time-series was completed and a shelf-wide survey from the CSS JOHN P. TULLY was carried out.

The series of snapshot transects will enable budget calculations on materials and the ability to follow response of the shelf/estuary to change in important controls such as light, ice-cover, temperature, and Mackenzie River input. While such a data set will promote understanding of what drives the seasonal progression, it won't be adequate enough to resolve processes which have smaller time scales (storms) nor will it be able to answer the question of how representative of the shelf the data set is. To address these shortcomings, four moorings, comprising current metres, transmissometers and sequential traps, were placed around the shelf (on the 200 m isobath). The moorings, recovered in spring 1988, provided the time signal of materials which drop out from the water column. The traps should have the seasonal productivity signal plus any terrigenous signal of materials which originate from the Mackenzie River. To tie observations along the transect to the larger scale of the shelf satellite, images were collected which specifically monitored ice-cover and distribution, sea-surface temperature and turbidity. Viewed in the river, the transect information will allow ground-tracking of the satellite data.

Complimentary programs were also conducted. Sediment-storm interaction was addressed. Observations on sediment pore-pressure, currents and optical back-scatter were taken successfully during two storms. Background microbial populations were measured before, during and following a storm, and their ability to degrade labelled hydrocarbons was tested. Colloidal hydrocarbons were analysed by cross-flow filtration techniques. Colloids are a potentially important contributor

to the hydrocarbon pool as they could consist in some cases of 100 percent hydrocarbon. Stations were maintained in the Mackenzie delta (inland waters) to monitor water flow and suspended solids, augmented with measurements on dissolved and particulate hydrocarbon and routine chemical determinations on the quantity and composition of material delivered seasonally to the Beaufort Sea. Samples were collected along the coast to determine composition of hydrocarbon in peat.

All aspects of data collection worked exceptionally well and moorings were retrieved with a data recovery of better than 90 per cent. Many support analyses have been completed either in the field or at IOS. Publication of data and interpretations is proceeding. *(Contact: R.W. Macdonald.)*

Ocean Ecology

(see Biological Sciences)

Data Assessment

The major functions of this group are facilitating access to scientific information and data and providing advice about the marine environmental effects of industrial development. The Division is also involved in coordinating regional planning activities within the Science sector and has been designated the first point contact within Science for a number of clients including DFO habitat management.

Climatology

In 1987, the B.C. Shorestation Oceanographic Program (BCSOP) obtained once-daily sea surface (one-metre depth) salinity and/or temperature data at 18 locations. Inactive since 1983, sampling resumed in January at Departure Bay, and in April at Nootka, an area which had not reported since June, 1953.

Monthly average temperature at several outer, exposed stations on the coast, such as Langara Island, were considerably warmer than normal during the first quarter of the year. At more protected stations, such as those in the Strait of Georgia area, temperatures in the early part of the year and in the autumn were much warmer than normal. At Entrance Island, temperatures reached values close to the historical maximum during both periods. Salinities were near normal along the entire coast throughout the year. *(Contact: L.F. Giovando.)*

Environmental Advisory Services

The Amauligak oil production proposal for the Beaufort Sea was one of the more significant projects reviewed during the year. Advice was provided on the acceptability of a proposal to initiate seasonal production; however the proponent decided to continue with exploration. *(Contact: B.D. Smiley.)*

The Arctic Regional Ocean Dumping Advisory Committee (RODAC) has formed two subcommittees--one for the eastern Arctic and one for the western Arctic--primarily by a desire to increase local participation in the decision-making process. Data Assessment still represents the Region on RODAC Arctic, and provides subcommittee advice through representatives in Yellowknife and Inuvik. *(Contact: R.C.H. Wilson.)*

Data Assessment continued to support RODAC Pacific by advising on conditions for ocean disposal permits. More than 70 applications for ocean dumping were assessed during 1987, over 30 per cent more than during the previous year. In addition to the usual permit requests for disposal of dredged sediment, two applications were received for the disposal of industrial waste under the Ocean Dumping Control Act (ODCA). One application, for James Island, involved the disposal of soil containing di- and tri-nitrotoluene, with minor lead and mercury contamination. Proposal review and subsequent concern over current patterns and possible effects on black cod led to a re-location of the site. The second application, involving spent pot-liners from the Alcan smelter at Kitimat, was withdrawn. *(Contact: L.F. Giovando.)*

Information Management

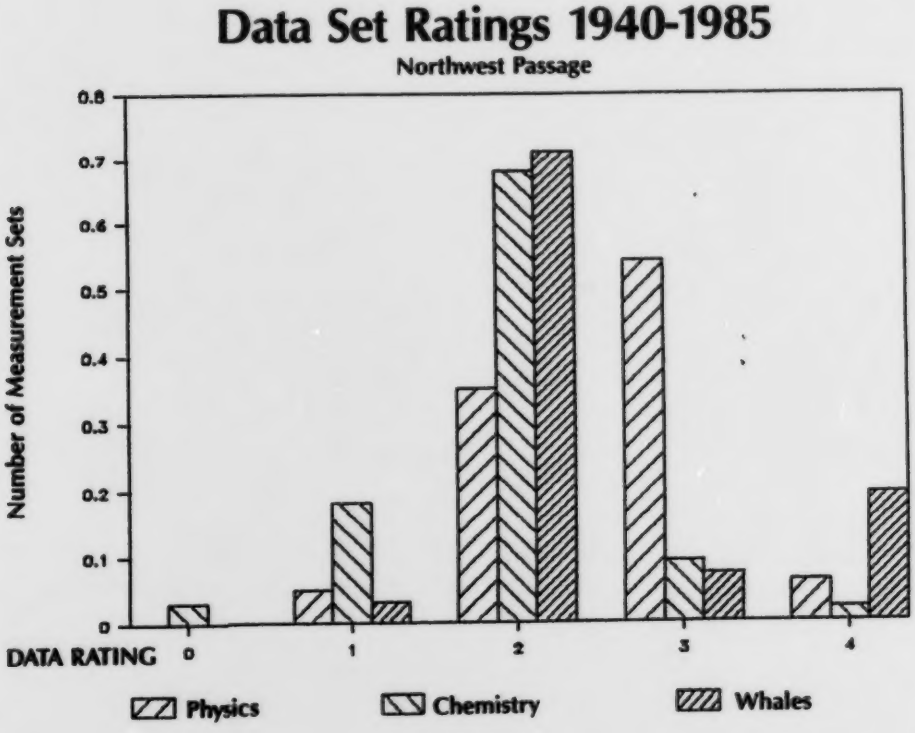
Data Assessment has been preparing comprehensive directories to oceanographic data since 1980 to meet the continuing need for complete but easy-to-use directories to ocean measurements. Scientists, engineers, impact assessors, planners, regulators and resource managers, all demand the directories, especially those who must use historical data for purposes other than those envisioned for the original studies. Inventories are being conducted and published of all existing data, either published or unpublished, analyzed or stored, public or proprietary, or of good, poor, or suspect quality. The directories offer a system which answers the "who measured what, where, how and when" questions before environmental or engineering studies can be made.

In 1987/1988, nine comprehensive directories were published. Each directory meets three criteria: the first, to compile available documentation about the collection, analysis and status of all historical oceanographic studies (data sets) within a discipline and a geographic area; the second, to objectively judge the reliability of all types of measurements reported in each data set, by scrutinizing the methods-and-materials documentation; and the third to summarize pertinent data set details in tables, maps, references, sources and indexes.

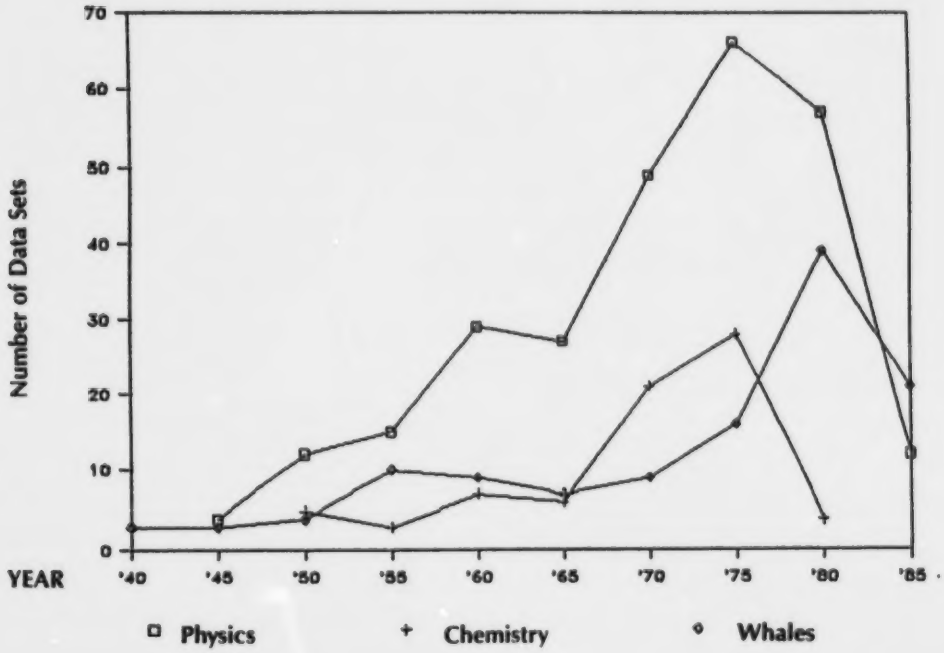
Since 1982, twenty catalogue directories dealing with sea temperature and salinity,

currents, water levels, waves, nutrients, trace metals, hydrocarbons, bacteria, plankton, epontic community, zoobenthos, fishes, seals and whales have been issued or reissued for Canadian Arctic and Pacific ocean waters.

Of particular interest has been the judged reliability of the data sets. Rather than the impossible task of examining the data, a semi-hierarchical data rating system can be used, which is based on the completeness of documentation on each type of measurement. While each requires its own criteria, the same five rating categories have been employed consistently throughout the system: 0) data are found or judged to be wrong; 1) data are suspect and probably not internally consistent; 2) data were not or could not be investigated because sufficient documentation was not available; 3) data are internally consistent and trends within the data are probably real, but comparison with other datasets may be difficult or impossible; 4) data are internally consistent and sufficiently standardized or tied to a reference, comparison with other "4 - rated" data should be possible.



Level of Effort in Northwest Passage



Several hundred data sets containing field measurements and observations of physical oceanography (1945 through 1985), chemical oceanography (1950 through 1981) and whales (1865 through 1985) for the central Arctic's Northwest Passage region were examined. Results show that the level of effort devoted to physical oceanographic studies in this region has been significant in each of the past four decades. In contrast, chemical oceanographic studies declined after a minor burst of activity in the mid-1970s, and whale research experienced exceptionally high attention during the same period.

The quality of the measurements produced by these research expeditions is significant. The reliability of between 35 per cent and 71 per cent of the historical measurements cannot be evaluated (rating of 2) due to inadequate documentation of the data set's methods of collection, storage and analysis (eg. no mention of type of sampling gear or depth of sampling). Without such basic documentation, measurements cannot be repeated nor applied with any confidence. Less than 20 per cent of all measurements (and as low as 2 per cent of chemistry data) warrant a top 4-rating. *(Contact: B.D. Smiley.)*

BIOLOGICAL SCIENCES

Biological Sciences

1987/88 was a year of beginnings, a year to build and use the strengths of the new science organization.

Individual project accomplishments are described in the pages of this publication, but some, because they cross sectional boundaries, or have an impact on the Biological Sciences Branch (BSB) as a whole, deserve special mention here.

The MASS (Marine Survival of Salmon) project progressed from a planning to an operational phase. This cooperative, multi-disciplinary project, designed to categorize and quantify the parameters affecting year class success in salmon, completed its first field season with participation by BSB, Ocean Physics, Ocean Chemistry and Hydrography. It is the start of a five-year research plan that will eventually expand to cover a wide area of the Pacific coast.

Following a successful examination and review of stock assessments for invertebrates, herring and groundfish, the Pacific Stock Assessment Review Committee (PSARC) completed its first intensive review of salmon stocks. Input and review by staff from BSB, Fisheries Branch and Resource Enhancement Branch, resulted in such a successful process that it has become an integral component in the development of DFO's Annual Fishing Plan for the Pacific Region.

The increasing challenges facing management, PSARC and the Canada/U.S. Salmon Treaty deliberations, precipitated an internal reorganization and realignment within Biological Sciences Branch. The Salmon and International Section was combined with the Recruitment Mechanisms Section to create two new Sections - Salmon Production and Salmon Dynamics. Salmon Production is responsible for all aspects of salmon stock assessment, sockeye salmon and Fraser lakes. Salmon Dynamics encompasses the fields of marine survival; coho, pink and chum salmon; and the impact of marine mammals on commercial fisheries.

A major highlight of the year was the first International Symposium on Recruitment and Errors in Stock Assessment Models. The three-day symposium, held in Vancouver in October 1987 under the joint auspices of the International Recruitment Investigations in the Sub-Arctic (IRIS) and the International North Pacific Fisheries Commission (INPFC), was organized and hosted by BSB staff. Thirty-five papers were presented by scientists from Canada, China, Japan, the United States and the Soviet Union. Publication of the proceedings is expected early in 1989.

In March 1988, the Honourable Tom Siddon, Minister of Fisheries and Oceans, officially opened the new West Vancouver Laboratory. This facility, which replaces

an old, inadequate structure with new laboratories, offices, coldrooms and an indoor and outdoor aquarium, represents the culmination of a plan initiated in 1966 when the site was originally purchased. It will become a scientific showplace for research in aquaculture biotechnology, habitat carrying capacity and resource enhancement.

Salmon Production Research

The Salmon Production section is made up of three program groups including stock assessment and biological advice to manage and conserve Canada's Pacific salmon resource, biological studies of sockeye salmon, and application of nutrients to sockeye nursery lakes as a means of production enhancement.

Salmon Stock Assessment

Stock assessment examines the biological productivity in salmon stocks to determine the desired spawning number, evaluates the present status of the stock relative to this number, and estimates expected salmon returns in future years. Biologists subsequently advise the fishery managers on allowable catches and assist in designing programs to develop the resource and/or improve the technical basis for assessments. The process involves the establishment of data systems, the evaluation of data reliability, development of analytic procedures and computer models, and research on the population dynamics of Pacific salmon.

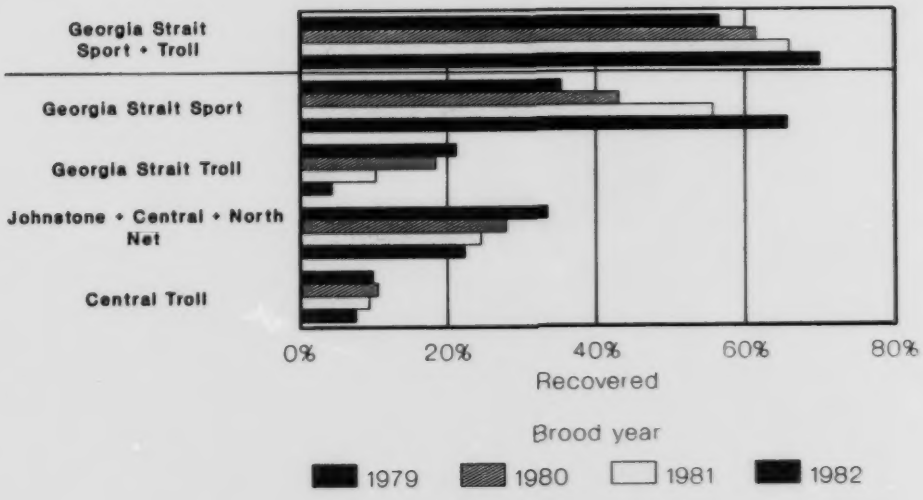
The Salmon Information Unit maintains three databases essential for assessments: historical catch, escapement, and the coded-wire tag data. In 1987, a major accomplishment was the establishment of coastwide reporting codes and formats for all American and Canadian coded-wire tag (CWT) programs to expedite the exchange of data between management agencies and to ensure consistent interpretation of the reported data. Extensive progress was also made in documentation and provision of user-friendly reporting and graphic programs. The group also established the escapement database as the regional focus for this data and prepared a specialized report for Habitat managers. Information requests from the public, and/or other scientists and managers were fulfilled. *(Contact: L. Lapi.)*

The Stock Interpretation Unit develops analytical methods and computer software to assist in assembling partial clues from available data into a coherent picture. For example, a study in 1987/88 led to a synthesis of lingcod fishery data related to catch, effort, biological samples, and tagging experiments. This shed new light on the status of lingcod stocks off the southwest coast of Vancouver Island. A second example is the analysis which showed that, on average, CWT estimates explain only

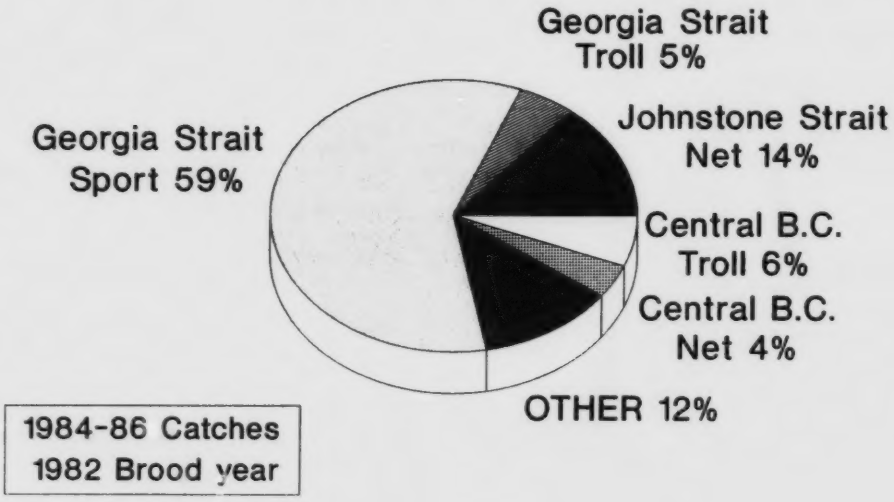
about 80% of the total return of tagged groups to B.C. hatcheries. The analysis demonstrated the importance of experiments to assess mortality of tagged fish, hatchery census methods, and straying of wild stocks into hatcheries. Staff in the Stock Interpretation Unit participate in the development of fish marking experiments, assessment methods for growth and mortality, stock identification techniques, and other biometric methods. In 1987/88, an extensive software package was produced for accessing the salmonid mark-recovery database. The Unit also directed a contract to develop two- and three-dimensional graphics software for general use in representing fishery data. *(Contact: J. Schnute.)*

Several significant assessment activities occurred in 1987. These included: 1) the establishment of a formal review process for stock assessments and advice provided for management (PSARC); 2) an indepth assessment of historical data on Fraser River sockeye productivity; 3) an estimate of total chinook catch in southern B.C. seine fisheries; 4) an evaluation of various forecasting models; 5) an extensive assessment and development of a chinook conservation program for the southern Strait of Georgia; and 6) the continued provision of advice to Canadian members of the Pacific Salmon Commission, the International North Pacific Fisheries Commission, and the Yukon River negotiations. *(Contact: B. Riddell.)*

Big & Little Qualicum
Chinook Catch 1981 - 86



Chinook Catch Distribution
Lower Georgia Strait Stock



Forecasting models were evaluated to produce accurate preseason forecasts of sockeye returns to the Adams River. A time-series approach provided the best results with mean forecast errors one half those produced using the cycle means as forecasts and 30% less than employing the Ricker stock-recruitment model. Combinations of individual models resulted in predictions that were comparable to the best time-series model. Consequently the use of several models may eventually provide the best forecasts. *(Contact: D. Noakes.)*

Sockeye Biology

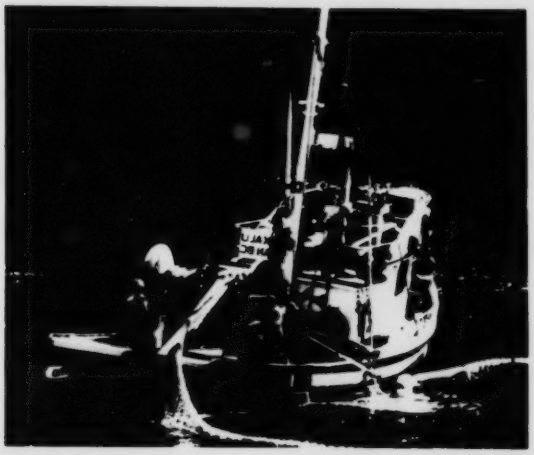
The Sockeye Biology and Assessment Unit has been conducting research on techniques for stock identification, factors limiting sockeye production in the Stikine, Taku and Alsek transboundary rivers, and the relationship between sea-run and landlocked (kokanee) forms of sockeye salmon.

Techniques for estimating the stock composition of sockeye catches in mixed-stock fisheries were further refined and evaluated. Simulation studies show that it is possible to reliably estimate contributions from up to 50 distinct sockeye stocks on

this coast by examining parasite, genetic, age and scale pattern "markers" in fish samples from the catch. However, since such a program is expensive to implement, more cost-effective alternatives are being investigated.

Eleven sockeye nursery lakes in the Stikine, Taku, and Alsek rivers were surveyed to determine whether the rearing habitat for juvenile sockeye was fully utilized, and to evaluate opportunities for enhancement. Several lakes were chosen for outplanting artificially-incubated sockeye fry with the objective of doubling adult sockeye production in the Stikine and Taku rivers. This enhancement project will be conducted jointly by Canada and the United States. Marking and sampling studies were continued in 1987 to determine the density, growth patterns, migration and residence of juvenile sockeye that rear in slackwater side channels of the lower Stikine River. These sockeye are atypical because they do not utilize nursery lakes and many migrate to sea in their first year of life. They account for approximately half of the total adult sockeye production in the Stikine River. Very little is known about limits to freshwater production of these sockeye populations, and hence, little is known about opportunities for their enhancement.

Alternative methods of capturing salmonids for tagging and sampling



Gillnetter

Taku River fish wheel

Stikine River

Glaciation.

Side channel habitat.

A genetic survey of 23 populations of sea-run sockeye and landlocked kokanee indicates that kokanee have evolved from sockeye on numerous occasions in different watersheds. Although genetically distinct even when spawned in the same streams, kokanee and their "hybrids" with sockeye salmon showed similar patterns of survival, growth, and adaptability to seawater when raised under identical hatchery conditions. Evidence suggests that either form can arise from the other, although there appears to be very little interbreeding in the wild. Thus, wild kokanee populations may be a convenient source of eggs for "sockeye" culture or for reestablishing sockeye runs to lakes where the sea-run form has been lost. *(Contact: C. Wood.)*

Fraser Lakes and Lake Enrichment

The Fraser Lakes and Lake Enrichment Unit conducts research on sockeye salmon production in freshwater and marine environments, specifically focusing on determining the carrying capacity of coastal and interior sockeye lakes and assessing the links between sockeye freshwater production processes and marine survival variations.

Plankton Research

Recent studies of the plankton ecology group at the West Vancouver Laboratory have focused on the characterization of the small picoplankton (0.2 - 2.0 um) communities of ultra-oligotrophic sockeye salmon nursery lakes. Photosynthetic picoplankton are the most important primary producers, responsible for 40% to 50% of the carbon fixation. The picoplankton carbon does not remain as a "sink", but moves, albeit inefficiently, to juvenile sockeye via the microbial loop, an important pathway that involves grazing by small protozoans and microzooplankton. Using scanning and transmission electron microscopy, new species of procaryotic algal picoplankton were discovered, as well as observations of small "minibacteria", and a variety of phycoviruses in the femtoplankton size range (0.02 - 0.2 um). These very small particles pass readily through conventional 0.2 um membrane filters and research is continuing to assess the significance of this potential loss on standard C primary production estimates and on measures of dissolved and particulate organic carbon. *(Contact: J.G. Stockner.)*

Fraser Lakes

The objectives of this program are to measure recruitment success, to investigate factors limiting production, and to determine methods for maintaining or enhancing sockeye production from Fraser River lakes. Emphasis is being placed on coordinated research into interactions between trophic levels and the effects of lake physics and chemistry on production. Efforts in 1987 focused on Shuswap, Chilko and Quesnel lakes with some assessment work on Harrison Lake.

Investigation into effects of varying fry densities and trophic status on Shuswap Lake will continue for four years. This study involves intensive sampling of all lake trophic levels, as well as physics and chemistry. Although Shuswap is a relatively productive lake, aspects of its physics and chemistry ensure that, for part of the growing season, much of the zooplankton community is unavailable to sockeye fry.

A similar study on Quesnel Lake, initiated in 1986, was continued in 1987. Fry densities were much lower than in 1986. In the Chilko Lake study difficulties were experienced in obtaining reliable hydroacoustic estimates of juvenile sockeye densities, making the enumeration of adults and smolts of prime importance in estimating both in-lake and marine survival. *(Contact: K.S. Shortreed.)*

Lake Enrichment

Since 1977, the Salmonid Enhancement Program has been funding aerial fertilization of sockeye salmon nursery lakes to enhance the juvenile recruitment and productivity of selected stocks. The application of nutrients to sockeye nursery lakes to increase sockeye production is being studied at several levels. Studies range from limnological and nutrient addition, to the biological utilization of these nutrients, and to the ultimate evaluation of whether production of adult sockeye is increased. In 1987, five sockeye nursery lakes (Great Central, Kennedy, Henderson, and Nimpkish lakes on Vancouver Island, and Long Lake on the central coast) received weekly applications of nitrogen and phosphorus fertilizers. All lakes treated in 1987 responded favourably and no changes in the treatment schedule were required.

Juvenile Sockeye Foodwebs

This study is investigating the role played by foodweb structure and efficiency in determining the carrying capacity of nursery lakes for juvenile sockeye. It also looks at how energy transfer from primary producers (phytoplankton) to sockeye is mediated and affected by dynamic foodweb processes. In 1987, field research focused on a comparative study of energy transfer from phytoplankton to the zooplankton forage of juvenile sockeye in a fertilized coastal lake (Kennedy) and a Fraser River lake (Cultus). In situ experiments were designed to measure size dependent rates of primary production and particle turnover, and particle selection and grazing by the micro- and macrozooplankton communities. The studies demonstrated how differences in the plankton community composition and foodweb structure of two lakes are reflected in the rate and efficiency of energy transfer to the zooplankton forage of juvenile sockeye. In Kennedy Lake, less than 5% of primary production was utilized by zooplankton (small cladocerans and copepods), while in Cultus Lake more than 30% of phytoplankton production was directed to the zooplankton food resources of sockeye. Thus, although two different lakes may have similar levels of primary productivity, the efficiency of energy transfer is a function of their foodweb structures. *(Contact: E. MacIsaac.)*

Enhancement Assessment

Research to determine conditions for use of nutrients to increase production of juvenile sockeye in coastal lakes continued. Experimental enclosure studies and empirical data indicate that the grazing pressure exerted by limnetic fishes has a much greater impact than invertebrate predators on zooplankton communities in coastal lakes. These studies suggest that when limnetic communities exceed a biomass of 10-15 kg per ha., production of sockeye juveniles is unlikely to respond to lake fertilization, without the development of other remedial measures.

The influence of changes in sockeye smolt size, smolt numbers, migratory timing, and stock location on variations in marine survival must generally be understood to permit assessment of the benefits of sockeye enhancement techniques and management of wild sockeye stocks for maximum yield. Research efforts continued to assemble time-series of observations on marine survival variations for various sockeye stocks, particularly those associated with Barkley Sound on Vancouver Island. Results to date suggest that sockeye stocks on the west coast of Vancouver Island exhibit similar temporal patterns of marine survival change which differ from other coastal locations. Differences in smolt size and migratory timing appear great enough to produce significant marine survival variations among stocks in the Barkley Sound region.

Future research will focus on the use of coded-wire tag releases and analysis of scale patterns to test hypotheses concerning the mechanisms responsible for variation in marine survival. *(Contact: K. Hyatt.)*

Salmon Dynamics Research

The Salmon Dynamics Section investigates causes of recruitment variation in salmon and herring off the west coast of Vancouver Island, and conducts research in support of stock assessment and fisheries management for Pacific salmon and marine mammals. The section is also involved in high seas research studies to evaluate interception of Canadian salmonids in high seas fisheries.

Marine Survival of Salmon (MASS)

The objective of the Marine Survival of Salmon Program is to determine the relationships between dispersal and survival of juvenile salmon off the west coast of

Vancouver Island and features of the ocean environment. During 1987, research focused on juvenile sockeye salmon from Alberni Inlet during their migration through Barkley Sound, and on coho and chinook juveniles on fishing banks off southwestern Vancouver Island.

Juvenile sockeye entered Barkley Sound in late April, were abundant during May, and were virtually gone from the sound by mid-June. Although there appeared to be some movement seaward along Trevor Channel on the southeast side of Barkley Sound, the principle migration was westward, across the landward end of Imperial Eagle Channel, through the Broken Islands, across the seaward end of Loudou Channel, exiting Barkley Sound past Amphitrite Point. Movement appeared to be continuous at about three to five km per day. Sonar and echo sounding studies in Alberni Inlet indicated that juvenile sockeye migrated in the upper 10 m of the water column. Migratory activity appeared greater on the ebb than on the flood tide and greatest migration occurred in association with a morning ebb tide.

Analysis of troll log book data collected from April to September during 1981-1983 off southwestern Vancouver Island indicated that aggregations of juvenile coho and chinook occurred mainly during May and September on Swiftsure, Finger, 6-Mile, and Amphitrite banks. Aggregations were always present on Swiftsure but were less predictable on the other banks. One explanation for the aggregations is that they are associated with stable circulation features (such as eddies) over the banks. Consequently, our hypothesis is that the aggregations should be disrupted during the spring and fall oceanographic transitions. Sampling on the fishing banks from September to November in 1987 did not clearly demonstrate a dispersal of aggregations following the fall transition, although juveniles did appear somewhat more evenly distributed among the banks in November. However, the species composition shifted from predominantly coho to a more even mixture of chinook and coho after the fall transition. A few pink juveniles were also present after the transition. *(Contact: M. Healey.)*

Recreational Fisheries Research

The majority of research effort in 1987/88 was spent on two projects: i) estimation of hooking mortality in sport caught and released chinook salmon, and ii) development of ways to verify the accuracy of sportfishing effort and catch estimates in Georgia Strait. Additional assessments of the abundance of fish, invertebrates and algae on the Nanaimo Harbour artificial reef were also conducted.

The unit also collaborated on three other programs in 1987/88: i) high seas salmon studies in the Japanese driftnet squid fishery area (referred to in the Ocean Mortality

segment of this section), ii) genetic stock identification of chinook salmon caught in the Georgia Strait recreational fishery and, iii) a study of overwinter ecology of hatchery produced chinook in the Quesnel River system (in conjunction with the Salmon Habitat Research Section and DFO Resource Enhancement Branch). In collaboration with Fisheries Branch and Habitat Management Branch, an information package on developing a recreational fishing pier was produced. *(Contact: T. Gjernes.)*

Salmon Biology

In the final year of a three-year sampling program, surveys on size, age, and biochemical genetic variation of Yukon River chinook were completed. Genetic differentiation was observed among some of the populations sampled in the Canadian portion of the drainage and all were well differentiated from an Alaskan population. Biochemical genetic methods of stock identification may thus be feasible for selected Yukon River chinook salmon runs.

A new project was initiated to evaluate the feasibility of using variation in nuclear DNA as a method of stock identification for chinook and coho. Preliminary results suggest that population-specific genetic markers may have been discovered for chinook salmon. A project was initiated to develop pink salmon spawning in even years in the Fraser River drainage system. Sexually mature pink salmon derived from the 1987 broodstock are expected in January or February, 1989. Heritability of morphometric and meristic characters of chum salmon maintained at three water temperatures, and the relationships between genetic and morphological variation in pink salmon was examined. A survey of variation in developmental biology of coho salmon in British Columbia outlining the effect of egg size, spawning time, and water temperature on alevin and fry hatching and emergence time was completed. *(Contact: T. Beacham.)*

Fisheries Oceanography

La Perouse

One of the main themes being tested by the La Perouse program is that survival of pre-recruit and adult herring is determined largely by the amount of spatial and

temporal overlap of the herring distribution field with the offshore predator field. Interannual variations in the amount and duration of overlap of these fields are believed to be responsible for significant variations in herring survival. Preliminary estimates indicate that offshore predators (Pacific hake, chinook and coho salmon, lingcod, sablefish and dogfish) have the potential to remove considerable numbers of pre-recruit herring, and between 30% to 50% of the biomass of adult herring annually.

Previous work indicates that year-class strength in the lower west coast of Vancouver Island herring stock is negatively correlated with annual sea surface temperature (SST) and the estimated biomass of Pacific hake. Both correlations were highest with a zero year lag for SST and a zero to one year lag for hake biomass. Hake is the single most important predator of juvenile and adult herring during the summer (June-November) when the distribution of this migratory species overlaps the distribution of herring on the continental shelf. An exploratory correlation analysis and existing field data suggest, as a working hypothesis, that temperature correlation may reflect the influence of oceanic conditions on herring survival during the first five to six months of life, which is spent largely inshore; while the hake correlation probably reflects the impact of this species on late age zero-plus and one-plus herring, which are distributed over the inner banks and basins on the continental shelf.

During the 1987 field season, the FRV W.E. RICKER and F/V CALEDONIAN conducted a joint hydroacoustic and trawl survey of the herring, hake and groundfish stocks off the lower west coast of Vancouver Island. The main objectives were: i) to map the distribution and diets of the dominant species encountered; ii) to obtain an index of abundance of pre-recruit herring; and iii) to measure the water properties and plankton biomass at the standard La Perouse CTD and plankton stations.

Between August 19 and 29, major concentrations of pre-recruit (age two-plus) and adult herring were located along the northern edge of "40 mile" bank and near the head of Nitinat Canyon along the 200 m isobath. A major concentration of juvenile herring (age one-plus and two-plus) was found on the southwest edge of Swiftsure Bank, and a minor one near Amphitrite Bank. The main body of hake was distributed around Finger Bank. Intensive sampling of the catch indicated that 6 1/2% of the hake had eaten herring, of which 8% were age zero-plus, 20% were age one-plus, 35% were age two-plus, and the remaining 35% were adults (age four and older). Significant numbers of herring also occurred in dogfish (7%), sablefish (8%), lingcod (56%), chinook salmon (30%) and halibut (38%). Preliminary estimates, which consider the average biomass of each of these predator stocks, suggest that the annual impact of hake on herring is about three to four times the impact of chinook and coho, about five times the impact of lingcod, and about eleven times the impact of sablefish and dogfish.

A qualitative index of the 1985 year-class herring strength was estimated from the relative abundance of age two-plus fish encountered during the survey. Based on age composition of the catch recruit spawners (age three-plus) were estimated as 29% of the spawning biomass in Barkley and Clayoquot sounds in March 1988. According to the age structured herring stock assessment model, a biomass of this proportion is of average strength. This forecast was presented at the September 1987 Herring Stock Assessment meeting and at the Herring Industry Advisory Board meeting, October 1987. This is the second year that offshore survey data have been used to forecast recruitment. Efforts will continue to improve recruitment forecast accuracy and to determine the sources of interannual variation in the survival of juvenile herring. *(Contacts: D.M. Ware and R.W. Tanasichuk.)*

Ocean Salmon Program

Field work was initiated on the MASS project. Staff conducted extensive sampling of juvenile salmonids and potential predators during the early sea-life period in Alberni Inlet and Barkley Sound. Substantial variation was documented between chinook, coho, and sockeye, and steelhead trout smolts in terms of residence times in near-shore areas and migration routes and timing. There was no evidence of significant predation on juvenile salmon by marine mammals or sea birds. The most important fish predators were Pacific hake, spiny dogfish, and walleye pollock. Predation mortality appeared low in 1987 with only 1.9% of the 924 fish predators examined having eaten juvenile salmon.

Development of the new beam trawls for sampling juvenile salmon from the FRV W.E. RICKER progressed to field trials. Substantial progress was made and most problems solved, opening up many new areas of investigation.

In 1987, staff conducted the third Canadian high seas research cruise to the North Pacific. Research indicated that salmon from North America were not being caught in significant numbers by Japanese driftnet vessels. The cruise also provided evidence that immature salmon were distributed much further south than previous data had indicated. Staff also participated in a cruise aboard a Japanese salmon research vessel operating in the Japanese land-based fishing area. Results from these cruises and other related international research activities were submitted to the International North Pacific Fisheries Commission (INPFC).

The fourth year of the West Coast Troll Log Project was successfully completed and an annual report distributed. One hundred and eleven commercial salmon troll vessels participated in the project. *(Contact: B. Hargreaves.)*

Coho Program

International and domestic management processes require substantial amounts of biological information to function effectively. Stock assessment and related biological advice on coho salmon was provided to the Pacific Salmon Commission and the Pacific Stock Assessment Review Committee (PSARC) as part of DFO's commitment to resource management. *(Contact: R.K. Kadowaki.)*

Knowledge of fish stock productivity parameters such as spawning escapement and exploitation rate which produces maximum sustainable yield is required for international and domestic fisheries management. In addition, an understanding of the relationship between habitat features and fish production is critical. In 1987 research into factors affecting these parameters for coho salmon continued on the Cowichan and Keogh systems on Vancouver Island, and the Lachmach River on the north coast of British Columbia.

The Mesachie Lake (Cowichan) program, a study of factors limiting productivity of wild coho stock, continued -- the second of a five-year investigation. Lake-reared smolts make up about 80% of total smolt production of 8,000. Smolts leave the system in spring and fall in roughly equal numbers. Survival may be reduced by lamprey (*Lampetra macrostoma*) attacks; more than 30% of the smolts were wounded, many severely. The fall movement of smolts out of Mesachie Lake appears to be part of a larger movement of lake and main-stem fish down the system and into sloughs and side-channels near the river mouth. Synoptic surveys throughout the Cowichan drainage system suggest that a significant part of the Cowichan smolt production over-winters in this limited habitat. *(Contact: L.B. Holtby.)*

In the Keogh River system, surveys monitoring the growth and abundance of juvenile coho in different freshwater environments (lakes, streams and main river habitats) continued. Dispersal patterns between these habitat types were documented and patterns of size and timing for wild coho smolts leaving the system were examined. *(Contact: J. Irvine.)*

Bio-physical surveys were conducted in July and August 1987 on the Lachmach River to investigate over-winter survival of smolts, and the relative importance to smolt production of various habitats in the watershed. To carry out the surveys, a temporary fence was installed and operated. Although 1,700 coho smolts were coded-wire tagged, it is believed the main portion of the run was missed because of high water washing the fence out on a number of occasions. A wooden fence deck was installed in July to facilitate future fence construction. A total of 6,000 juvenile coho were marked in late fall and early spring. *(Contact: B. Finnegan.)*

The stream indexing project is evaluating whether counts of adult coho salmon in certain segments of a stream can be used as indicators of the abundance of salmon in

the entire stream. The main objective is to determine and develop appropriate sampling designs that could be used by field workers for more reliable and accurate estimates of spawning escapement. In 1987, work was carried out in French Creek, Black Creek and the Trent River. In all three systems, adult fish counting fences and mark-recapture estimates of coho escapement are available to evaluate the accuracy and precision of expanded instream counts. Results are promising although it is clear that different approaches are required for different types of streams. *(Contact: J. Irvine.)*

The stream indexing project is also examining whether trends in escapement in properly chosen index streams represent trends for other streams in the same area. For the third consecutive year coho escapements to Black Creek, French Creek and the Trent River were accurately monitored. Escapements were significantly less in 1987 than in the previous two years. Numbers of adult coho returning to other systems in the area, including Quinsam Hatchery, Puntledge River and Big Qualicum River, were also lower in 1987. Although this suggests that coho escapements are correlated with one another over time, it may be necessary to collect data for up to ten years before the utility of between stream escapement indexing for coho in streams draining into the Strait of Georgia is properly tested. *(Contact: J. Irvine.)*

A cooperative research project with the University of British Columbia continued to measure variation in marine harvest patterns between certain Vancouver Island coho stocks, and to examine the differential vulnerability of hatchery and wild stocks to fishing. A separate investigation assembled and reviewed information on the length of time Pacific salmon spend in freshwater prior to spawning. Unpublished information gathered from the operation of coho smolt and adult enumeration fences in Black Creek from 1978-1980 is also being assessed. *(Contact: J. Irvine.)*

Work continued on factors affecting potential colonization as an enhancement technique for coho salmon. Assessments of second year smolt production from Grant Lake and first year production from two stream study sites in the Koksilah River watershed were made. Fry to smolt survival for Grant Lake was similar to that observed in 1986 (18.9%); however, construction of a plastic pipe bypass around a series of cascades is expected to significantly increase smolt to adult survival rates. Coded-wire tags were applied to emigrating smolts for the first time to enable evaluation of ocean survival and fishery contribution rates. In addition to the two stream sites in the Koksilah watershed, Quamichan Lake in the Lower Cowichan River was planted with both hatchery and wild salvaged fry. Grant Lake was not replanted in 1987. To date, healthy growth rates have been observed in all planted systems with Quamichan Lake exhibiting phenomenal growth. *(Contact: R. Bams.)*

DFO participated in assessing the consequences of the proposed Sage Creek

Company open-pit coal mine, to be located just north of the Canada-U.S. border in southeastern British Columbia. In April 1985, the International Joint Commission established the Flathead River International Study Board to investigate the water quality, biological (including fisheries), and water use implications of this proposal. Four international technical committees addressed the problem and the Biological Resources Committee completed its report in 1987. DFO was similarly involved in a sub-committee defining ambient water quality criteria for selected variables of the Canadian portion of the Flathead River basin. The report of this committee was completed in 1987. Extensive studies on the Kemano Completion proposal of the Aluminum Company of Canada, initiated in 1980, were also completed. *(Contact: H. Mundie.)*

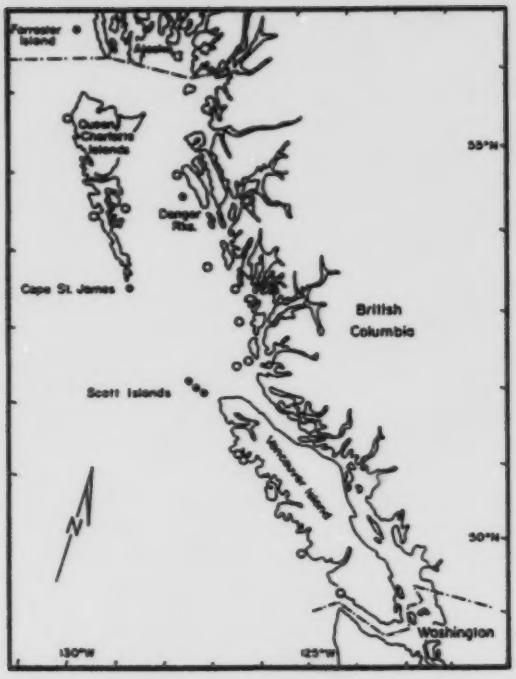
Marine Mammals

Sea Lions

Field work continued to monitor long-term trends in the abundance of Steller sea lions on the British Columbia coast. A province-wide aerial census was undertaken in early July 1987. Approximately 4,800 animals (including 1,100 pups) were counted on breeding rookeries, and 2,400 animals on non-breeding haulouts. The population has not increased appreciably since being protected in 1970. Earlier censuses of rookeries indicate the current population represents only about one quarter to one third the number in the early 1900s. The decline was due to predator control kills and commercial harvests.

A census taken on the large breeding rookery on Forrester Island, just north of the British Columbia/Alaska border showed about 6,100 animals (including 2,100 pups). This rookery increased steadily until the 1970s, but has since stabilized. Growth of this rookery may account for the lack of recovery of the British Columbia population.

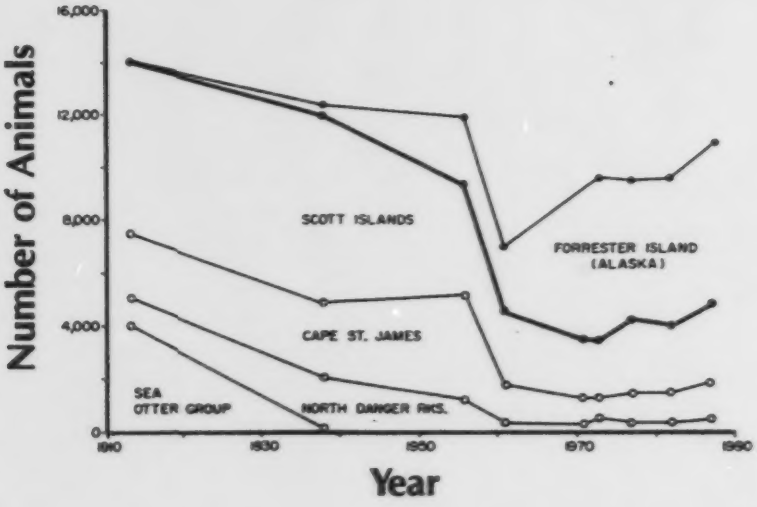
A census of the wintering population of sea lions off southern Vancouver Island was taken February, 1988. Approximately 3,000 California and 1,200 Steller sea lions were counted. Numbers of California sea lions wintering in British Columbia increased dramatically during the 1970s and early 1980s, peaking at 4,500 in 1984, and have subsequently stabilized at approximately 3,000 to 3,500. The wintering population of Steller sea lions has fluctuated between 700 and 1,200 since the early 1980s. *(Contact: P. Olesiuk.)*



Steller Sea Lions

- ● Breeding Rookeries
- ○ Summer Haulouts

Steller Sea Lions
(Numbers on Breeding Rookeries)



Harbour Seals

Research effort on harbour seals increased substantially this year in response to growing concerns over their impact on valuable fish stocks, particularly salmonids. Aerial censuses were conducted in the lower Skeena River, off southwestern Vancouver Island and in the Strait of Georgia. These indicated that populations are continuing to increase at about 12.5% per annum. Counts in the lower Skeena River increased to 1,250 in 1987 from 400 in 1977, and in the Strait of Georgia to 12,500 in 1987 from 2,100 in 1973 . The total B.C. population is currently estimated to be about 65,000 compared to 15,000 in the early 1970s. The increase represents the recovery of populations depleted by control kills and commercial harvests.

Studies are focusing on the impact of harbour seals on salmon stocks in the Strait of Georgia, particularly in estuaries. This involves the collection of scats for diet determination, censuses to establish seasonal movement patterns and observations of feeding behaviour. Regions of high priority are the Cowichan, Chemainus, Nanaimo and Puntledge estuaries. Aerial censuses are being undertaken in the Strait of Georgia throughout the year to establish seasonal movement patterns and are being expanded to other areas to enable more precise population estimates. *(Contact: P. Olesiuk.)*

Killer Whales

Long-term studies of the general biology of killer whales continued, using photo-identification of individual animals. These studies show that two distinct forms of killer whales, resident and transient, inhabit coastal waters of British Columbia. The current population is composed of about 255 residents and 75 transients. Residents form two communities. One extends from central Vancouver Island to Prince Rupert and consists of 16 pods with 175 members. The other extends from central Vancouver Island to Puget Sound and the west coast and consists of 3 pods with 80 members. The transient population ranges throughout British Columbia and is composed of 28 pods.

The resident form of killer whales exhibits a social structure that appears to be unique among mammals. Individuals spend their entire lives in the pod in which they were born. Consequently, each pod represents one or more matrilines. A typical matriline consists of a grandmother, her adult son, her adult daughter and her adult daughters' offspring. *(Contact: M. Bigg.)*

Other Marine Mammals

Other marine mammals were studied opportunistically. From June to September 1987 an aerial census of the sea otter population off northwestern Vancouver Island was undertaken in conjunction with other agencies. Although the count was incomplete, the population probably numbered between 400 and 500 individuals. A more comprehensive census is planned for 1988/89.

In cooperation with local volunteer groups, cetaceans that washed ashore dead were examined. A dead false killer whale was stranded at Denman Island on May 3, 1987, and another temporarily live-stranded near Ucluelet on July 28, 1987. These animals were apparently part of a pod of about 12 individuals sighted in local waters during May to July, and represent the first records of this species in British Columbia. *(Contact: M. Bigg.)*

Groundfish Research

The landed value of the groundfish fishery continued its dramatic rise in 1987, approaching $85 million. The objective of groundfish research at PBS is to provide the scientific basis for rational management of approximately 60 stocks of fish. Groundfish research is designed to determine the maximum (or optimal) yield from each species, a process which involves four steps: identification of individual stocks within species; determination of annual and seasonal abundance and production; determination of biological properties such as growth, longevity, natural and fishing mortality rates, fecundity and life history; and development of mathematical models incorporating parameters which can simulate the response of a stock to fishing and non-fishing environmental factors. Studies recently initiated will develop more complex modelling, involving relationships between stocks of different species occupying the same fishing grounds.

In particular, studies in 1987 focused on three areas. The first is the development of increased understanding of recruitment variation through studies of reproductive biology and effects of the biological and physical oceanographic environment on survival trends for egg, larval and juvenile stages, spawning timing and spawning conditions. Projects are being carried out in the Lingcod-Rockfish Program, the La Perouse Project and the Hecate Strait Project. The second study is examining biotic and abiotic factors which determine year-class success, particularly for sablefish, Pacific cod and Pacific hake. The third study focuses on incorporating sources of variability into models using simulation techniques.

Stock Assessment

Staff begin groundfish assessments in the spring of the year using a multi-year database for fishery statistics and biological research. Assessments and estimates of potential yields from 42 groundfish stocks are completed after review by a committee of groundfish scientists. Review may also incorporate outside investigators (government or non-government). Assessments are then reviewed by the Department of Fisheries and Oceans Pacific Stock Assessment Review Committee (PSARC) and recommended yield options sent to fisheries management staff.

In early October, fishery managers and BSB scientists meet to review a draft management plan. It is at these meetings that alternative management scenarios are examined and their impacts assessed. A management plan is finalized and presented first to the Pacific Groundfish Advisory Committee (government and industry) and then to industry as a whole at public meetings in Vancouver and Prince Rupert in early November.

This review and consultation cycle is augmented by ad hoc meetings with industry representatives to address specific issues dealing with groundfish stock assessments. In addition, an annual meeting is held with industry to review research activities leading to the preparation of assessments and development of yield options for management recommendations.

Scientific staff met several times with the Deep Sea Trawlers Association (DSTA) to develop a joint plan with industry to begin an innovative survey program for rockfish. If the plan, which is not yet finalized, is initiated, fishing companies will contribute vessel time to conduct systematic surveys that meet scientific standards to establish a new long-term series of rockfish abundance.

To gain a greater appreciation of the observations on the condition of fish stocks which are made by captains of commercial vessels, research personnel participated in nine commercial trips during the year. In addition to observing catch rates and fish distribution, researchers also collected biological samples.

Monitoring of commercial groundfish catches at dockside continued. Port samplers collected biological samples from commercial landings for most of the important trawl-caught species and recovered tags and logbooks from both trawl and trap vessels. The logbook data is maintained as an interactive database for both research and real-time management needs.

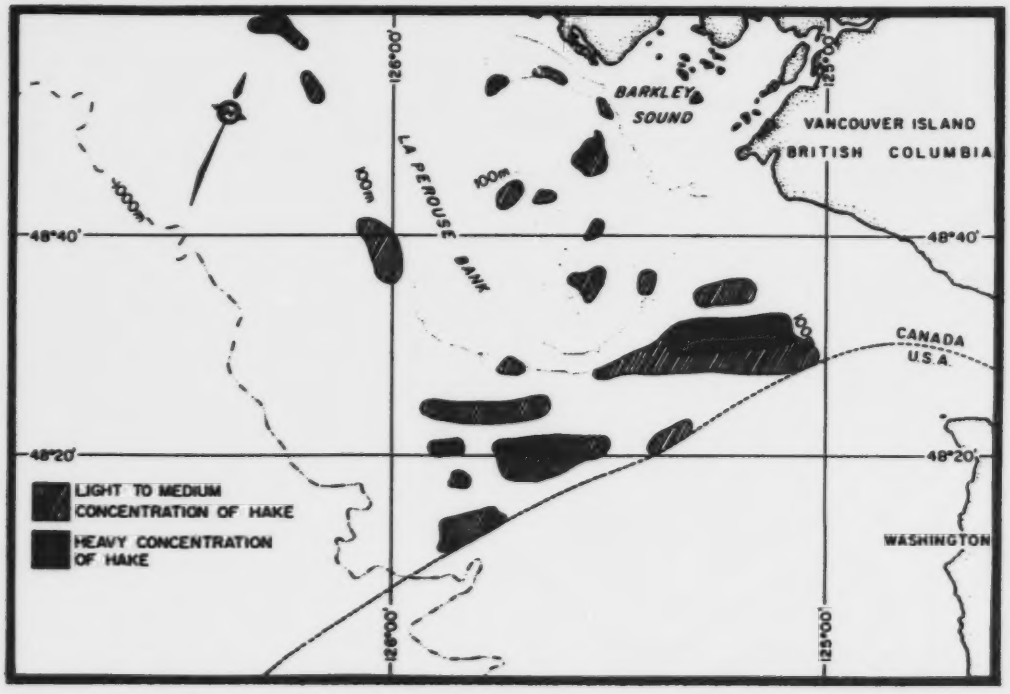
Field tests of a computerized logbook system for trawlers continued. The system is available commercially and a software application has been developed to convert

the system's bridgelog files, generated by the vessel skipper, to a format compatible with the DFO database.

Pacific Hake

Trawl landings of Pacific hake are a major component of the groundfish fishery. During 1987/88, research was conducted on the Strait of Georgia inshore stock and the west coast of Vancouver Island stock. The offshore stock, distinct from the Strait of Georgia stock, ranges from California to northern Vancouver Island.

Hydroacoustic and swept-volume trawl surveys were conducted in the Strait of Georgia to estimate Pacific hake biomass and to collect biological samples.



Distribution of hake around La Perouse Bank during August, 1987

In August, a species interaction trawl survey of offshore Pacific hake was conducted. The survey, conducted annually since 1985, is part of the longer term La Perouse Project. The objectives of this study are: 1) to determine the distribution and relative abundance of Pacific hake on an annual basis; 2) to examine distribution in relation to oceanographic and biological features; and 3) to determine the impact of Pacific hake and other predators on the abundance of Pacific herring. The results of the 1987 survey, the 1986 U.S. triennial trawl/hydroacoustic survey, and our recent assessment of the total stock indicate that Pacific hake are at the highest levels since monitoring first began in the 1960s.

In addition, studies continued to investigate the reproductive response of Pacific hake to exploitation and differences in age- and size-specific fecundity and age-at-50% maturity between three hake stocks: offshore, Strait of Georgia and Puget Sound. *(Contact: G.A. McFarlane.)*

Sablefish

A survey to examine the relative abundance and distribution of sablefish larvae off the west coast of Vancouver Island was conducted in April and May. Correlation of the survey abundance index with abundance of the year-class recruiting to the fishery will begin in 1988.

Biological and oceanographic data collected as part of the La Perouse project were used to examine biotic and abiotic factors influencing year-class success. In addition, a species interaction trawl survey was conducted in August to assess the impact of sablefish and Pacific hake on herring stocks on La Perouse Bank.

Approximately 2,000 juvenile sablefish were tagged and released off the west coast of Vancouver Island, as part of Canada's commitment to the International Juvenile Sablefish Tagging program.

Rearing of larval sablefish was continued. Eggs collected at sea and from hormone-induced captive broodstock were used successfully. Experiments were conducted to determine the appropriate time of presentation and size, density and type of food organisms required to bring sablefish through the larval stages. *(Contact: G.A. McFarlane.)*

Spiny Dogfish

Approximately 4,000 spiny dogfish in the Strait of Georgia, 4,000 off the west coast of Vancouver Island and 2,000 off the northeast coast of Vancouver Island were tagged in 1987 as part of experiments designed to measure exchange between the Strait of Georgia and offshore stocks. Preliminary results indicate that exchange between inshore and offshore areas may be greater than previously believed. Fish tagged offshore are highly migratory with recaptures verified from as far south as California and as far north as the Gulf of Alaska and Japan. *(Contact: M.W. Saunders.)*

Offshore Rockfishes

Slope Rockfish

Electrophoretic analysis of allozymes from Pacific Ocean perch (*Sebastes alutus*) stocks off British Columbia showed no isolation of adult fish for the enzymes examined. Stocks, which are shown by analysis of their parasites, to be separate at the adult stage showed genetic distances similar at levels 0.99 between Dixon Entrance and Vancouver Island. These results imply that while groups of adult Pacific Ocean perch may be separate at the adult stage, there is genetic exchange among them for the enzymes investigated. Whether this exchange is maintained by juvenile recruitment or seasonal adult spawning movements remains to be determined. Genetic analysis also showed lower levels of enzyme heterozygosity in older fish, compared with younger fish of both the same and different sizes. This result for a long-lived fish differs from those of similar studies for shorter-lived organisms. *(Contact: B.M. Leaman.)*

An analysis of length-at-age data for Pacific ocean perch was initiated to determine if these data could be used to examine the question of long-term growth changes, and why older fish (40 y) are generally smaller than middle-aged fish in this long-lived species. Results suggest there is an inverse relation of growth and survival rates, but that length-at-age data obtained over limited time periods are inadequate to resolve the competing hypotheses of either time trends in growth or growth-survival interactions. A model to permit the resolution of this problem for the general case was constructed and confirms that a combination of several different rates of asymptotic growth, correlated with survival, can give rise to a distribution of lengths-at-age yielding smaller, older fish. Biological support for such multiple growth types was found through electrophoretic analysis, which showed genetic distinction of these older fish. *(Contacts: B.M. Leaman and T.J. Mulligan.)*

Shelf Rockfish

Biological sample data, collected in 1985 and 1986 from the west coast of Vancouver Island, were examined to quantify the prevalence of a parasitic copepod, *Sarcotaces arcticus*. There was a prevalence of 2.5% in silvergrey rockfish *(Sebastes brevispinis)*, and 0% in canary rockfish *(S. pinniger)*. Prevalence declined with increasing size in silvergrey rockfish. In addition, a lower proportion of infected specimens were reproductively mature, implying a metabolic cost to infection. Prevalence was variable between years and among areas. *(Contact: R.D. Stanley.)*

Inshore Rockfish and Lingcod

The handline/troll and longline fisheries for inshore species of rockfish have grown rapidly in recent years. Stock assessment advice for these species has been hampered by a lack of both fishery and biological data. To obtain more accurate information on catch and effort, a logbook program was initiated in 1986 for the commercial fishery. In addition, biological sampling of the commercial catch was continued and three research survey cruises were completed in different areas of the fishery. The impact of the fishery is obvious on heavily exploited stocks, as indicated by a decrease in the average size of rockfish in those stocks over the past two to three years.

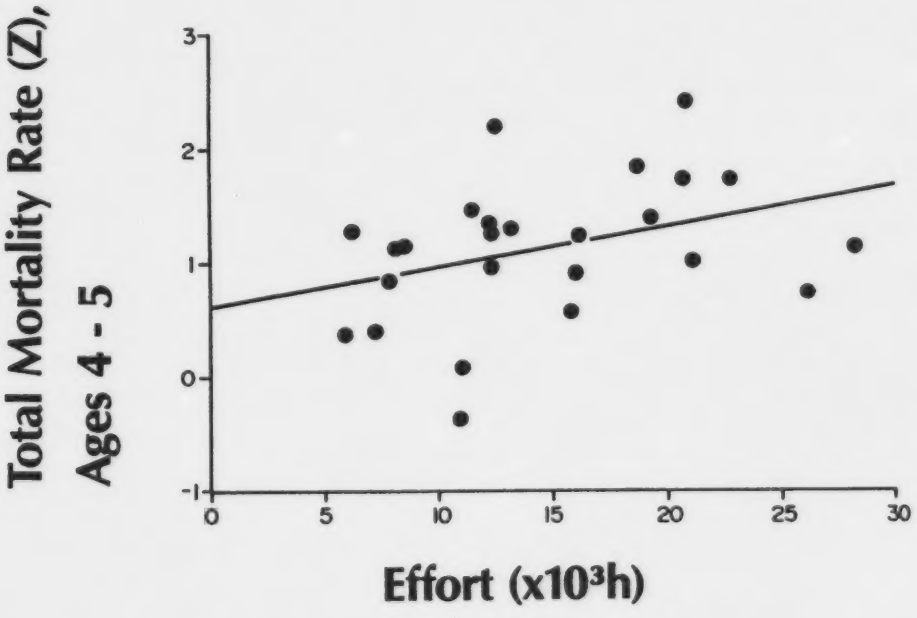
A major analysis of existing biological and fishery data was completed for the lingcod stock off southwest Vancouver Island. The analysis utilized recent advances in stock assessment methodology to determine the biological impact of the fishery. Growth rates, based on the length distribution of commercial samples collected since 1956, agreed remarkably well with growth rates based on length-at-age and tag-recovery data, providing an indirect validation of lingcod ageing techniques. The analysis suggested that lingcod recruitment has decreased over the past 10 to 15 years and that the natural mortality rate of lingcod in the fishery is about 25% annually. The most plausible interpretation of the fishery data is that lingcod stocks on the trawl grounds are maintained by immigration from nearby non-trawlable areas.

Other work on lingcod included a survey in the Strait of Georgia, designed to improve our understanding of decreases in commercial catches in that area. *(Contact: L.J. Richards.)*

Hecate Strait

The final species assemblage survey was conducted in Hecate Strait in May and June. Two previous surveys facilitated a comparison of summer and winter distributions of on-bottom fish, while the third allowed an assessment of interannual variation in the summer groups. Results from cluster analysis of the data indicated very little interannual variation.

During the summer, northern Hecate Strait is dominated by spiny dogfish, rock sole, Pacific halibut and large skate in shallow depths (10-40 fathoms) and by Pacific cod, English sole, rex sole and Pacific sanddab at deeper depths (41-79 fathoms). Southern Hecate Strait is characterized by rockfish, arrowtooth flounder and Dover sole.



Overall fish assemblages remained fairly stable during the three year study period. However, changes in relative abundance were observed for some species. Most dramatic was the significant increase in relative abundance of Pacific cod, due to the presence of a large 1985 year-class. In contrast, Pacific sanddab and rex sole showed little change in abundance and distribution between years.

The May-June cruise also provided information on food resource division within the species assemblages. A total of 605 stomachs were collected from 19 species. Analysis of stomach contents collected on cruises in June and September 1985, January 1986 and May-June 1987 is underway. Results from this analysis will be used to establish the trophic linkages between members of the different on-bottom fish assemblages. *(Contact: A.V. Tyler.)*

Flatfish

Ovary samples for a study of the reproductive biology of English sole were obtained during research cruises in May-June and November, and observer trips in March and August 1987. Determination of the size-frequency distribution of oocytes in the various samples has begun. Changes in the gonadosomatic index are also being monitored. Data collected thus far indicates a peak spawning period in October for English sole, with spawning continuing as late as March the following year.

The burnt-otolith cross-section method of ageing was validated for rock sole. Using age composition data derived from this technique, an estimate of the rate of natural mortality (M) of 0.21 was calculated for the species. The oldest fish aged from commercial samples was a 17-year-old female. Age composition for rock sole is now being updated for catch-at-age analysis.

An analysis of the effects of temperature and stock size on rock sole year-class production in Hecate Strait was completed. The relationship between temperature and year-class strength was dome-shaped with temperatures of about 6.3 deg. C associated with optimum year-class production. The analysis also suggested the existence of a Beverton-Holt stock-recruit relationship for the species.
(Contact: J. Fargo.)

Pacific Cod

A study of the reproductive biology of Pacific cod continued in 1987 with three research cruises and two observer trips to collect ovary samples for histological examination. Determination of oocyte size frequency distributions was initiated. Samples were also collected for fecundity estimation. The relationship of fecundity to length was determined, indicating, for example, that the average 65-cm female (age four) has 1.8 million eggs.

Data from research and port samples was used to show the extent of geographic and interannual variations in length at 50 per cent maturity in Hecate Strait. Length at 50 per cent maturity from north to south varied from 57 to 43 cm. Among years at White Rocks Ground, it varied from 38 to 56 cm.

Mortality rates were re-estimated using the Paloheimo Method based on successive ages of cohorts. The rates, based on the changes in numbers of fish as they progressed from age-4 to age-5 were considered to provide the least biased estimates of mortality rate. This is because recruitment to the fishery was incomplete for age-3 fish in the early years of the time-series; while numbers of age-6 fish were substantially biased due to ageing errors. Rates that were estimated included total instantaneous mortality rate (Z), instantaneous natural mortality rate (M), and instantaneous fishing mortality rate (F). M was estimated using the method of regression of Z versus hours of fishing effort with M equal to the statistical intercept at zero hours effort. The regression was statistically significant, and the resulting estimates were: Z = 1.13; M = 0.61; and F = 0.52. These high rates are consistent with earlier estimates and indicate that the stock has a rapid turnover, with 66% of the fish dying of natural or fishery causes each year.

A stock assessment of Pacific cod in the Strait of Georgia was published which, for the first time, included yield-per-recruit analysis. At M = 0.6, minimum commercial size = 41 cm and mesh size = 11.43 cm (4.5 inches), a maximum yield of 360 g per age-1 recruit was achieved at F = 0.7, giving an exploitation rate of 39% per year of the available stock. *(Contact: A.V. Tyler.)*

Fish Age Determination Unit

The Fish Age Determination Unit aged approximately 10,000 groundfish, (sablefish, hake, lingcod, Pacific cod) and 38,000 herring. A total of 6,600 salmon were aged, using 15,500 scales and 500 otoliths to assess ages. Non-ageing activities included the processing and sectioning of 1,300 pectoral and dorsal fins from 700 chinook salmon and the digitizing of 4,300 sockeye salmon scales.

A number of ongoing projects were continued including; developing, validating and documenting salmon, groundfish and herring ageing criteria; developing a precision testing system; and computerizing sample inventories.

Validation work included completion of ageing of 500 oxytetracyline-injected lingcod using the fin-ray cross section method. Preliminary results indicate this method is accurate. In addition, staff believe they have discovered a natural tag (i.e. growth zone character) on the otoliths of a very strong 1980 year-class from the

offshore hake stock as documented from 1986 catches. Monitoring of this characteristic for validation purposes will continue over the next few years.

Collaborative projects involved staff at the Pacific Biological Station; representatives of regional, national and international levels of government; and the college and university communities. Such projects included participation in a chinook salmon scale resorption study using samples from a number of B.C. hatcheries; the provision of data for identification of international sockeye salmon stocks; and examination and ageing of sockeye salmon scales from the USSR for possible identification of characteristics that could be used to describe continent of origin. *(Contact: S. MacLellan.)*

Sablefish Mariculture

Full utilization of sablefish stocks by the domestic fleet and the increasing demand in Japan and North America for a quality product has stimulated interest in developing a sablefish mariculture industry.

A comprehensive multidisciplinary study has been initiated aimed at developing the technology required to establish a successful culture industry. To date, success has been achieved in developing techniques for the capture and transport of all life history stages of sablefish, including procurement of eggs from the field; developing techniques for induced ovulation and spermiation of sablefish using hormonal treatments; developing fertilization and incubation techniques for both wild and induced eggs; determining optimal salinity and temperature conditions for incubation of eggs and yolk-sac larvae; and determining acceptable food organisms, their particle sizes, densities and their presentation in time, that are required to bring larvae through to the postlarval stage successfully. In addition, studies have also focused on optimum growth conditions for post larval and juvenile sablefish; determining nutritional requirements and development of diets for juvenile and adult sablefish; and determining baseline fish health data from wild stocks to assist in the recognition of future disease problems that could occur during rearing.

Results from the energetics study indicate that sablefish have excellent food conversion capabilities, even on modest diets. They also appear to have an adaptable physiology which is flexible enough to compensate for the changing metabolic needs associated with a variable food supply. *(Contact: G.A. McFarlane.)*

Shellfish Research

The Shellfish Section provides biological and scientific advice for managing, protecting, and developing the region's invertebrate resources and marine plants with specific functions as follows: to undertake research on the distribution, life history, ecology, physiology and behaviour of commercial and potentially commercial invertebrate and marine plant species; to carry out resource surveys and sampling of commercial catches for stock assessments of invertebrate and marine plant species; to participate in research on the impact of natural and man-induced factors on the habitat of invertebrate and marine plant stocks; to maintain fishery databases and to develop analytical methods, including the use of theoretical models; and, to provide biological advice to management staff and to communicate research results to fishermen, industry and the scientific community.

Scallop Culture

Scallop culture research during 1987/88 was again directed primarily at two species, the exotic Japanese scallop (*Patinopecten yessoensis*) and the native rock scallop (*Crassadoma gigantea*). In addition, preliminary culture research was done with the Chilean scallop (*Argopecten purpuratus*). This latter species is a reasonably large, fast-growing scallop that is hermaphroditic and remains in spawning condition throughout most of the year. Studies of these three species together enables experimental breeding studies to be carried out over a greater portion of the year.

All Japanese scallop broodstock used in the past year was produced in previous years' spawnings in the laboratory. In 1987/88, fewer spawnings were attempted with Japanese scallops, but because of improved hatchery techniques, a larger number of larvae (17.3 million) were raised to the mature stage. This is an increase of 20% over the previous year. About 50,000 juveniles (larger than 5 mm shell height) remain alive. About half the scallop larvae produced in 1987/88 were sacrificed in experimental work, mostly in studies on the effect of nutrition on scallop energy reserves.

Four successful spawnings of Chilean scallops were carried out and preliminary experimental work was done to determine optimum conditions for raising larvae. At present, about 5,000 juveniles of this species are under culture and will be used as broodstock in future work.

Development continued in improving nursery technology to quickly grow newly settled scallop spat to an out-planting size with minimal mortality. Preliminary results indicate that a sudden reduction in temperature improved the settlement

success of metamorphosing larvae as compared to indecisive results when chemical stimuli were used. Firmly attached spat grew and survived best when placed immediately after setting in the open environment. When held either in tanks with recirculating water and added food or in tanks with unfiltered surface water from Departure Bay continuously pumped through them, performance was poorer.

Juvenile Japanese scallops produced in 1986/87 were placed at eight locations along the British Columbia coast (Prince Rupert, Queen Charlotte Sound, Clayoquot Sound, two locations in Barkley Sound, north end of the Strait of Georgia, Departure Bay and Sansum Narrows) to assess growth and mortality rates to commercial size (10 cm shell height). Regular monitoring was carried out at each site with final analysis to be concluded later in 1988. *(Contact: N. Bourne.)*

Bivalve Survival

Microanalytical procedures were developed to determine biochemical components from which energy levels and condition indices of larvae (100-250 ^{e}m) were derived. Energy levels in larvae of *Patinopecten yessoensis* declined during early development, were then maintained by endogenous reserves present at the egg stage, and then increased as the larvae reached premetamorphic condition through effective assimilation of food supplied by algal diets. Nutritional condition and ultimate survival of metamorphosed larvae were therefore dependent on the nutritional quality of the spawned eggs, shown to be variable with broodstock used, and on diet. Evaluation of biochemical components in phytoplankton species indicated that *Chaetoceros gracilis* was best for conditioning broodstock to improve egg quality. The rate of decline in energy reserves, particularly of lipids in starved premetamorphic larvae of *P. yessoensis*, was twice that in larvae of either *Crassadoma gigantea* or the Pacific oyster, *Crassostrea gigas*. This indicated that during metamorphosis, a period of little energy uptake, the larvae of the latter two species have twice as long to effect morphogenic change before energy depletion occurred and the larvae died.

Feeding trials on larvae of *P. yessoensis* and *C. gigantea* showed no significant correlations between either dietary protein or lipid, and growth rate or nutritional condition of the larvae. However, a significant correlation between dietary carbohydrate and larval quality illustrates the important role carbohydrate plays in tissue synthesis as opposed to activity.

A procedure was developed for direct, in situ preparation of fatty acid methyl esters from lipids in freeze-dried tissues. Incorporation of essential polyunsaturated fatty acids, eiccosapentaenoic and docsahexaenoic acids, into *P. yessoensis* larval tissue was shown to be dependent on their inherent content in phytoplankton diets. The presence of these acids in phytoplankton lipids is species-dependent and to ensure a

complete nutritional complement of essential fatty acids, appropriate mixtures of algal species in diets fed to larvae were necessary.

Fatty acid profiles of larval *Crassostrea gigas* and *P. yessoensis* differed, with the former having a higher level of nonmethylene-interrupted docosadienoic acid. This acid, considered to be endogenously synthesized from dietary monoenoic acids, indicates a fundamental difference in the lipid dietary requirement of these two scallop species. *(Contact: J.N.C. Whyte.)*

Fishery Studies

Monitoring of three experimental prawn management systems in Howe Sound, Salmon/Sechelt Inlets and Alberni Inlet was conducted to assess the impact of fishing on population age structure. In addition, research assessment cruises were conducted in Howe Sound and Salmon/Sechelt Inlets to obtain data on stocks during periods when the commercial fishery was closed. In 1987, recommendations to stop fishing in Howe Sound in late winter were implemented to take advantage of a rapid growth period. When 1987 landings were compared to 1986 landings, which had a later winter opening, the overall number of prawns caught in 1987 was reduced by 21 per cent but the total weight of prawns landed was 13 per cent higher than in 1986. *(Contact: J.A. Boutillier.)*

Further experiments to improve the escapement of undersize prawns were conducted with wire mesh traps designed by the prawn fishery. Results will be incorporated into the conditions of licence for the 1988 prawn trap fishery. To prevent growth overfishing of prawn stocks, escape mechanisms to provide increased opportunity for escapement of sublegal size prawns from all prawn traps will be required in 1988. *(Contact: J.A. Boutillier.)*

The study of *Sylon*, a parasitic barnacle, continued. This parasite was found to infect more than 40% of prawns in some populations in the northern regions of B.C. While prawn populations in southern regions are uninfected, *Sylon* does infect a number of closely related shrimp species. Causes of this difference in preferred hosts are currently being investigated. *(Contact: J.A. Boutillier.)*

Stock assessment of shrimp off the west coast of Vancouver Island confirmed the 1985 prediction of an increase in shrimp. A survey found strong two-plus and moderate three-plus age classes of shrimp. Commercial landings from this area exceeded 1,800 t, the highest since the late 1970s. *(Contact: J.A. Boutillier.)*

A computer program was developed to summarize catch and bridge log information

recorded during assessment cruises or in connection with commercial fisheries monitoring. The program generates summaries of catch or catch-per-unit-effort for each sampling unit in terms of weight or number of pieces landed. Written in ANSI standard FORTRAN 77, the program has been successfully implemented on IBM PC and VAX computer systems. *(Contact: D. Noakes.)*

Individual summaries of shrimp trap logbooks submitted by fishermen to DFO were sent to designated licence holders. These reports summarize catch by month and statistical area. Feedback from industry has been positive. This initiative will be expanded in FY 88/89 to include the shrimp trawl logbook program. *(Contact: J. Fulton.)*

Fisheries performance and species biology of both targetted flying squid (*Ommastrephes bartrami*) and by-catch species were again monitored in an experimental driftnet fishery by Japanese and Canadian vessels in offshore waters. Fishing performance in recent years has been published and biological data on the major species caught continues to be processed. Following the second year of a substantial increase in marine mammal by-catch, an indefinite moratorium on driftnet fishing for flying squid was announced by the Minister of Fisheries and Oceans. *(Contact: G.S. Jamieson.)*

The suggested high mortality of sexually mature, prerecruit male crabs observed in an 1986/87 study resulted in a repeat study in 1987/88 to determine survival rates of these crabs. Overall abundance of this age class had decreased substantially during the year, but about 1,100 predominantly prerecruit crabs were tagged and their abundance monitored over the winter. Theoretically, most should molt in the spring and then be quickly caught in the commercial fishery in 1988. Relative abundance will be established at that time and mortality rates determined. *(Contact: G.S. Jamieson.)*

Recruitment Studies

Two cruises were conducted in Howe Sound to obtain samples for initial work on prawn larval studies. Further prawn larval studies are planned. *(Contact: J.A. Boutillier.)*

A computer program, developed to graphically summarize wind- generated onshore transport from hourly meteorlogical data, has been employed to study recruitment of Dungeness crab (*Cancer magister*) on the west coast of Vancouver Island. The computer program provides summaries of actual onshore transport during a specific time period, cumulative onshore movement and the maximum

onshore transport occurring during a specified time interval. Program development and enhancement will continue in 1988/89. *(Contact: D. Noakes.)*

Aspects of the biology and early life history of Dungeness crab (*Cancer magister*) were again investigated in the intensive fishery off Tofino on the west coast of Vancouver Island. Large juveniles and adults were monitored in trap and trawl surveys every three months to monitor seasonal and annual shifts in population structure. Factors influencing settlement of larval crab megalopae off the west coast were monitored in two cruises off the west coast of Vancouver Island and Washington. Megalopae were abundant in offshore waters, but while there was some settlement at Tofino in May, most megalopae were again apparently prevented from coming onshore by the presence of the Vancouver Island Coastal Current. This current does not occur off the outer coast of Washington and settlement there was more substantial. Overall landings of crab, which first enter the fishery as three year olds, are expected to peak in 1987 at Tofino. The last high settlement of crab was in 1983. *(Contact: G.S. Jamieson.)*

In 1987, larval studies on Dungeness crab in Juan de Fuca and Georgia Straits were initiated with a series of three-day cruises each month between April and September. Megalopal occurrence was highest in July, in contrast to May-June peaking in abundance observed in outer coast waters. This work provided initial data for a more extensive two-week survey on the abundance and distribution of Dungeness crab megalopae scheduled for the summer of 1988.
(Contact: G.S. Jamieson.)

Mussel Culture

Most research on mussel culture in 1987/88 involved analysis of extensive data collected in 1986, but studies did continue at five of the eighteen sites previously studied: Indian Arm, Okeover Inlet, Booker Lagoon, Tzartus Island and Departure Bay. Untagged mussels in the 30-35 mm size range were cultured in pearl nets from May 1987 to April 1988, repeating for a second year the May-October study and for the first time, providing data on growth and survival over the winter. Sampling was at six-week intervals. Results, which have only been partially analyzed to date, agreed with 1986 observations that growth and survival of mussels was best at selected locations. Future work is being planned to establish why this is so and to evaluate further the potential of enhancing culture by using "strains" which seem to have the most positive culture attributes. *(Contact: G.S. Jamieson.)*

Herring Research

The primary objective of herring research at PBS is to provide the scientific basis for the conservation and rational management of this resource in B.C. In order to provide biological advice on stock status and catch recommendations for herring fisheries, the major focus of research in recent years has been related to stock assessment. This work includes development and evaluation of analytical assessment methodology, development of spawn survey techniques, larval and juvenile surveys, evaluation of hydroacoustic assessment methods, stock identification and species interactions research.

Stock Assessment

The annual herring stock assessment process begins in the spring with the collection of biological data during the roe herring fisheries and surveys of the subsequent spawning escapement. During the 1987/88 season, 102 samples from 9 roe fisheries, 261 prefishery charter samples, and 30 research samples were collected and processed for biological data. This information, required for stock assessment, is incorporated into a database of historical data from 1950 to the present.

Using two assessment methods – an escapement model and an age-structured model -- stock assessments are conducted annually for seven major migratory herring stocks . Both methods were revised this year to incorporate additional biological structure and spawn research information. Additionally, bootstrap techniques were developed to estimate confidence intervals on stock forecasts from the age-structured model.

Stock assessment results are presented in September to the Pacific Stock Assessment Review Committee (PSARC) to determine fishing quotas based on the best available biological data. In 1987, although PSARC recommmended closure of the Queen Charlotte Islands to commercial roe fisheries in 1988, the coastwide quota was higher than in the previous year. *(Contact: V. Haist.)*

Spawn Surveys

Adult herring spawner escapement is estimated from spawn surveys. There were three types of surveys in 1987/88: surface surveys, Fishery Officer diving surveys

(FODS), and research-oriented diving surveys. In addition, a project to investigate egg loss in herring spawns was initiated.

Research diving surveys include sample harvesting for egg counts. In April 1987 a survey was conducted on the lower east coast of the Queen Charlotte Islands. The survey corroborated stock assessment model estimates of low stock levels. Consequently, the Queen Charlotte Islands were closed to roe fishing in 1988. Approximately 25% of the spawn was deposited on the giant kelp (*Macrocystis* sp.) and 75% of the eggs were deposited below mean low water to depths of 15 m.

FODS, conducted on most of the coast in 1988, are modified research diving surveys with limited sampling for egg counts. Egg density is estimated from visual observations with a predictive model. Over the past three years, BSB has assisted in training Fishery Officers by involving them in research diving surveys. Spawns not surveyed by divers were surveyed using traditional surface survey techniques.

The egg loss study, conducted in Barkley Sound in March 1988, included repetitive sampling of spawns, censusing of avian predators and collection of bird stomachs. In Barkley Sound, an estimated 30,000 birds were present, of which approximately 14,500 gulls and 13,500 scoters and other duck-like birds were feeding on herring spawn. *(Contact: C. Haegele.)*

Juvenile Distribution and Abundance in Georgia Strait

Herring recruit to the roe fishery primarily at age three when they can constitute 50% or more of the spawning run. Therefore, forecasts which assume historical average recruitments can be significantly inaccurate. Information on distribution and relative abundance of a cohort at an earlier stage in the life history should result in more accurate forecasting of the size of annual spawning runs.

The first year of the Georgia Strait juvenile survey concentrated on locating fish and developing sampling procedures that could provide representative samples of the available stocks. Surveys to examine the distribution and relative abundance of young-of-the-year or juvenile herring were conducted each month from June through September in Jervis Inlet, Stuart Island, Campbell River, and Lambert Channel. Juvenile herring occurred in small schools throughout all these areas and growth rates were identical among all areas. Attempts made to capture immature and adult fish from non-migratory herring stocks resident in Georgia Strait were largely unsuccessful and will require a more concerted effort in 1988. Non-migratory herring, thought to be an important food source for coho and chinook stocks, do not

contribute to the roe fishery. Very little is known about the size and distribution of these stocks. *(Contact: J. Schweigert.)*

Hecate Strait – Winter Herring Survey

A hydroacoustic survey cruise on the FRV W. E. RICKER in November 1987 assessed herring stocks in Hecate Strait. The objectives of this, and three similar cruises in the fall and winter of 1985 and 1986, have been to survey broad areas and plot the major fall and winter distributions of herring in Hecate Strait, examine the stability of this distribution over time, and examine the feasibility of hydroacoustic assessments of herring biomass. In addition, the short-term variation in herring distribution, diurnally and geographically, was examined in detail.

Results to date indicate that winter herring distributions are predictable and are related to major spawning distributions. The major winter distributions are the Browning Entrance area and Juan Perez Inlet on the southeast shore of the Queen Charlotte Islands. Browning Entrance appears to be the major winter location for northern herring spawning on Porcher Island and Chatham Sound. It is possible that herring which spawn in Chatham Sound may overwinter in locations other than the general vicinity of Browning Entrance. However, despite extensive searching, no other large winter herring concentrations have been observed. Such searches have not been made in adjacent Alaskan waters.

Using data collected on the November 1987 cruise, a hydroacoustic biomass estimate and distribution information on north coast herring was provided in January 1988, prior to annual herring roe fishery surveys. Further development, with refinements of hydroacoustic hardware and software could facilitate the collection and assessment of abundance data at sea.

One puzzling observation made during the November 1987 cruise was a high incidence of tumour-like growths in the herring ovaries. Shipboard examination of approximately 400 fish indicated that 10% to 20% of females in the Queen Charlotte Islands were affected. It appeared that the posterior, ventral portion of the ovaries was misshapen and discoloured. There are indications that the problem was observed in the herring roe processing industry in 1988, and will be assessed during a cruise scheduled for December 1988. *(Contacts: B. McCarter and D.E. Hay.)*

Larval Herring and Other Larval Fishes in Hecate Strait

Surveys of larval herring were made in 1985 and 1986, approximately three weeks after major spawning activity. Subsequent to field collections, samples of larval herring and other larval fishes have been analysed in the laboratory with assistance from summer students.

Sample analyses were completed under contract in the fall of 1987, and the data is currently being analysed. Three tentative conclusions have been drawn. Distribution of herring larvae appears to be confined mainly to near-shore locations. In general, there was more dispersion of larvae along the coast than from near-shore spawning areas to deeper, offshore locations. Almost no herring larvae were taken in mid-Hecate Strait. Secondly, distribution of larvae between two major northcoast spawning locations, Kitkatla Inlet or Porcher Island and Chatham Sound, was continuous in both years. By virtue of the larvae mixing between the adjacent but geographically separate spawning sites, there is probably only a single large stock on the northern mainland coast. Third, all fish larvae captured in 1986 were smaller than those taken in 1985, with differences in mean length and mean weight. This cannot be attributed to difference in larval ages because the two surveys were made approximately at the same times each year and larval ages have been estimated by comparing time of capture with the date of spawning. The implications of these observations will be discussed in a later report. *(Contact: D. E. Hay.)*

Recruitment Forecasting

This project forecasts year-class strength for the seven herring stock groupings on the B.C. coast. Herring populations fluctuate substantially, and magnitudes of year-class strength have been highly variable over the period of 1951-1986, increasing the need for accurate and timely forecasts.

Analysis of historic recruitment estimates, obtained from analytical assessments, led to the development of recruitment models for the major herring stocks. The Ricker model, the Ricker-Environment model and the Transfer Function Noise model were evaluated. For each stock, the model which provided the best fit to the historic data was used to make numerical recruitment forecasts for 1988. Work on evaluating forecasting procedures using nonsymmetric loss functions is in progress.
(Contact: M. Stocker.)

Stock Identification

The apparent complexity of herring stocks continues to make concise descriptions of populations for stock assessment difficult. In addition to historical tagging information, morphometric and meristic characters, truss networks, and genetic characters have been collected for some areas from 1983 through 1986. Comparison of truss networks and conventional morphometric and meristic data indicates that truss analysis provides a more comprehensive description of fish shape and so is a better separator of groups of fish. Because of the small sample sizes, few significant differences were detectable among the four groups of herring examined. Similarly, electrophoretic and mitochondrial DNA analysis has revealed no significant genetic differences among the stocks tested. It appears that herring stock structuring may occur at a localized spatial scale which can only be detected by more extensive sampling of specific spawning sites. *(Contact: J. Schweigert.)*

Species Interactions

During summer 1987, chinook and coho stomachs were collected in an attempt to learn more about the trophic relationships between salmon and herring. To estimate the impact of salmon predation on herring, an estimate of the maximal loss of herring to salmon predation is required. Because this varies according to annual fluctuations in herring and salmon abundance, the observed predation rates will be crude. The greatest concern about salmon dependence on herring as a source of food is in the northern Strait of Georgia. In this area most chinook and coho salmon and herring are migratory, leaving the strait to feed in the open ocean; however, some individuals of all species remain in the strait for their entire lives. Recent stomach analysis of chinook collected during the summer in northern Georgia Strait showed that up to 70% of their diet was herring - in contrast to their diet elsewhere where herring are taken by salmon but in much lower relative quantities. Analyses of coho stomachs differed between 1986 and 1987. In 1987 coho had a higher frequency of herring in their stomachs. Most of the herring eaten by the coho were young-of-the-year, of the small sardine-sized (8 cm) herring that are frequently raked for bait. Chinook salmon took a variety of herring sizes including some adult-sized herring. One tentative conclusion of this work is that coho may eat large quantities of juvenile herring. Another is that chinook may eat large quantities of both resident and juvenile herring.

Investigations into predation by seabirds of herring and other fishes in Georgia Strait were undertaken. Findings indicate that herring are often a vital food resource for marine seabirds. While there are other large stocks of marine fishes in the strait,

particularly groundfishes, and periodic episodes of high abundance of small seaward-migrating salmonids and smelts in summer, juvenile herring provide a longer-duration food base in summer months and overwintering adult migratory herring provide a source of food during winter months. Findings of the investigation were presented in a multiauthored paper to a December 1987 symposium at IOS on the ecology and status of marine birds in the Strait of Georgia. The symposium was sponsored by the Pacific Northwest Bird and Mammal Society. *(Contacts: D. E. Hay and B. McCarter.)*

Forecasting Spawning Timing

The herring roe fisheries make Pacific herring the most valuable commercial fish species on the Pacific coast. Prices are highest for ripe herring roe, falling dramatically for less ripe roe. The challenge for managers of the herring roe fisheries is to stage an opening when the herring are fully mature but before spawning begins. The forecasting procedure consists of monitoring the rate of increase of the gonosomatic index (GSI) (i.e. percentage of female total weight made up by roe), and estimating when females will be fully mature. A detailed analysis of in-season and historic data indicated that modifications to the procedure were required in order to deal with instances of more than one maturity group co-existing. It was also necessary to develop a more accurate equation for estimating GSI at spawning. With these modifications, the date of peak maturity in Barkley Sound herring was predicted three days in advance in 1987 and five days in advance in 1988. Data analysis has also disclosed factors which have considerable influence on maturation and the timing of spawning itself. These are important to the method as well as to understanding herring spawning biology. *(Contact: D. Ware.)*

Ocean Ecology Research

The Ocean Ecology Group investigates both natural variations and the consequences of man-induced stress in marine planktonic and benthic ecosystems to provide advice and prediction of real or anticipated impacts of natural variability (e.g. El Nino or climate change) and of human activity (e.g. fishing activity, habitat destruction or disposal of pollutants). The plankton program focuses on understanding the linkages between ocean variability and responses of the lower components of the marine food web on a wide spectrum of time and space scales.

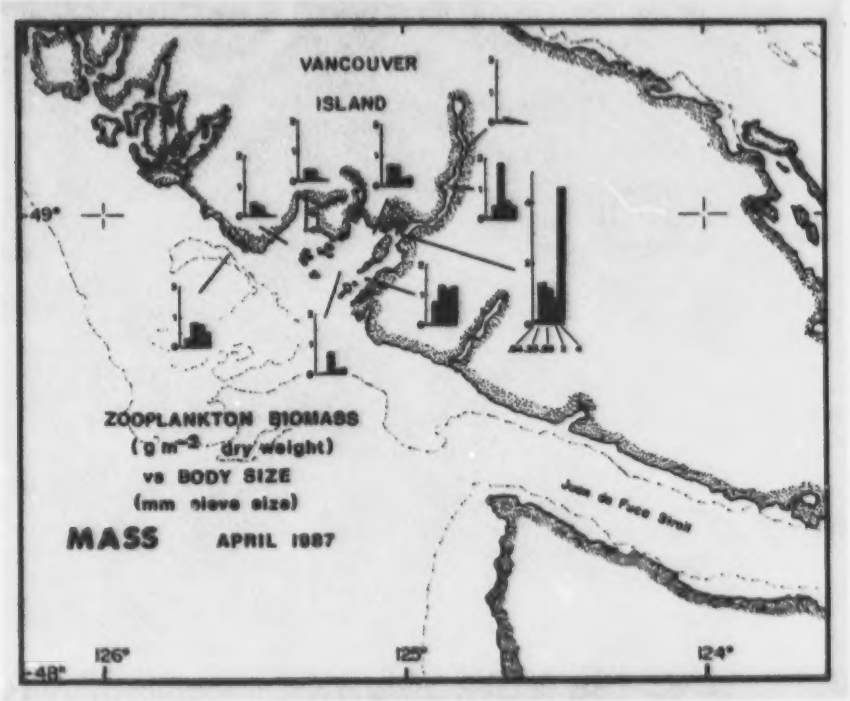
The benthos program focuses on the description of the benthic community in a natural state, its response to stress, and the use of that response as an indicator of broader ecosystem change as a result of the imposed stress.

Plankton

Plankton research activities in 1987 continued in the Subarctic Pacific Ecosystem Research project (SUPER), the La Perouse project, and the Coastal Transition Zone project. In addition, new investigations were undertaken for the Marine Survival of Salmon project (MASS) and planning was started for the International Joint Global Ocean Fluxes Study (JGOFS). Techniques were developed or improved for transmission of satellite imagery to ships, for estimating grazing and growth by microzooplankton, and for the analysis of phytoplankton pigments by high pressure liquid chromatography (HPLC).

In May and June 1987, a cruise on the CSS PARIZEAU, in conjunction with U.S. scientists on the RV THOMPSON, was conducted to the centre of the Alaskan Gyre (near the Ocean Station Papa site). Objectives were to determine the 24-hour cycles in the small scale vertical distributions of phytoplankton and zooplankton and related physical and chemical variables, to observe horizontal variations in near surface currents, and to carry out pilot experiments on microzooplankton. As results from an initial cruise in 1984 suggested, phytoplankton and zooplankton are both located in layers in relation to physical gradients with some species of zooplankton migrating into different layers at different times of day. Natural stimulated fluorescence of phytoplankton is so strongly inhibited in sunlight near the sea surface that it can be used as an indicator of the strength and extent of wind-driven mixing. Three satellite-tracked drifters drogued to follow currents between 10- and 20-metre depths were deployed in a right angle triangle 30 km on a side to determine whether advection of plankton by surface currents follows the wind and is spatially uniform. While the outer two drifters followed the wind, the middle drifter travelled at right angles to the others during the five days that they were deployed, indicating there is significant pattern or variability in surface currents. Thus plankton populations cannot be assumed to be simply slowly and uniformly drifting with the wind.

As part of the MASS project, Ocean Ecology staff analyzed zooplankton samples taken from Alberni Inlet and Barkley Sound during April 1987. The main objective was to determine inlet-scale spatial variability in primary production and standing stock of different size classes of phytoplankton, and in standing stock of different sizes of zooplankton—to find out whether food chain production was sufficient to feed the juvenile sockeye emerging from Alberni Inlet and if fish were found in areas with more abundant food supply. Highest total biomass and greatest relative



abundance of large-bodied zooplankton coincided roughly with the region of high juvenile salmon abundance. A more detailed study is planned for 1988 .

In July a study investigated the upwelling filaments that flow offshore across the continental shelf off Vancouver Island. As in 1986, an upwelling filament originated off Brooks Peninsula and branched into two arms: one flowing offshore and one flowing southward along the shelf break. Both phytoplankton and zooplankton abundance was several times higher than in adjacent waters, indicating the role of these filaments in exporting planktonic fish food away from the coastal corridor where the juvenile sockeye are presumed to migrate on their way to the open ocean. In addition, current speeds of 20-50 cm/sec within the filaments certainly would affect the directed swimming of juvenile salmon. In 1988 a study is planned to determine if and how the juvenile salmon migrate around Brooks Peninsula in the face of the episodic offshore-flowing upwelling filaments.

The joint IOS/PBS La Perouse Project is investigating interannual variability in commercial fish stocks, plankton and physical oceanographic processes on and around the La Perouse fishing bank. Zooplankton net tow samples were analyzed from six occupations of the La Perouse grid during 1987. Three years of sampling

has allowed the construction of information on an annual cycle and on year-to-year variations in that cycle. After three years of sampling, only the inner banks and basins show a clear annual cycle, but relative abundances of larger zooplankton are greatest at the shelfbreak and beyond. Periods of highest abundance of larger zoooplankton occur when salps (not a preferred fish food) are very abundant, as they were through the sampling area during summer 1987.
(Contacts: K.L. Denman and D.L. Mackas.)

Benthos

Three field programs were active this year. In October, fifty-six samples were taken in Vancouver Harbour on a joint cruise with Environment Canada (DOE) staff, aboard the CSS VECTOR. A reference station off the West Vancouver Laboratory was used for comparisons of samples in the inner, central and eastern sections of the harbour. Staff from DOE were sampling the sediments for contaminants and trawling for large organisms. Fish were examined for possible health-related sublethal effects of contaminants. Half the samples have been sorted into major taxonomic groups, and it is evident there is a diverse fauna in the inner harbour. There is some indication of faunal depletion in the other two sections of the harbour where there is a large concentration of industry and less water circulation. The analyses will be completed during 1988-89. The same sampling stations will be used in an 1988-89 investigation of toxicological impacts of contaminated sediments. This investigation will be carried out by consultants supported by the Ocean Dumping Research Fund. The IOS contribution will be a complete assessment of the macroscopic infauna, organisms such as clams and polychaete worms which inhabit the soft sediments.

The benthos group, joining a cruise on the CSS JOHN P. TULLY in January 1988, obtained samples from Dean Burke Channel, Douglas Channel and Portland Canal. These will be used to build an inventory of conditions on the bottom of selected British Columbia fjords, some of which are already subject to multiple use. Intensive studies of Alice Arm have already been published, as have studies of Hecate Strait and the continental shelf off Barkley Sound. All information will be published in a comparative publication, and may be discussed at the Canadian Continental Shelf Seabed Symposium in Halifax in 1989.

New methods that allow statistical significance to be assessed within and between the results of cluster analyses of benthic data used in environmental assessment have been distributed to government agencies and consulting companies. Publication of this information, in summer, 1988, is expected to lead to a wider interest in this approach.

Collecting benthic samples

Identification services for aquatic annelids have continued. In a collaborative effort with American and Argentinian scientists, a guide to the fauna of South and Central America and primary publications related to that area have been completed. Cooperative work with scientists of the People's Republic of China, Japan and Nepal should lead to a revision of the fauna lists for Asia (outside the USSR). Soviet colleagues have adopted the style of our faunal guides in preparing a guide to the Oligochaeta of the USSR.

Theoretical studies on the evolution of leeches, oligochaetes and related groups have progressed well. Athough some rare fish parasites have been obtained from fishery biologists in Alaska, Canadian biologists have not observed them in many northern lakes that have been sampled for salmonids. Preliminary analyses suggest that the textbook accounts of evolution have overemphasized adaptive features shared by many predatory forms, and there is little real relationship between the various groups involved. All are clearly annelids, but as yet very little more can be said. This work is again a team effort, with Canadians, Americans and Italians.
(Contact: R.O. Brinkhurst.)

Fish Health and Parasitology Research

This section conducts research on the distribution, causes, prevention, and control of a variety of finfish and shellfish diseases; and on parasites of fishes. Research on parasites is directed at minimizing or reducing economic losses from their effects on fish health and on market acceptance of fish products, assessing the impact of parasites on ocean survival of juvenile salmon, and using parasites as natural biological tags for fish stock identification. The section works closely with the aquaculture industry and the regional Resource Enhancement Branch in the provision of diagnostic services and advice on disease control measures, participation in fish health workshops and courses, administering the Canadian Fish Health Protection Regulations, and in monitoring quarantine facilities. *(Contact: L. Margolis.)*

Fish Health Research

Further studies conducted on methods to prevent the egg-mediated transmission of *Renibacterium salmoninarum* (Rs), an important disease in cultured salmon in British Columbia, indicated that injection of broodfish with the antibiotic erythromycin (20 mg/kg fish) 10 to 56 days prior to spawning resulted in levels of non-leachable antibiotic in the eggs which are likely to be effective. The feasibility of treating eggs directly to free them of intra-ovum Rs was also studied. Therapeutic levels of erythromycin could be infused into the eggs if a) a carrier substance such as propylene glycol was also present, and b) if the infusion took place while the eggs were still soft (i.e., not water-hardened). In addition, to ensure successful fertilization rates, the infusion had to take place following insemination. Further work on the procedure is needed to determine whether a safe but effective combination of treatment time and carrier concentration exists. Combinations of these factors tested to date resulted in unacceptable egg losses. *(Contact: T. Evelyn.)*

A study was initiated to determine whether resistance or susceptibility to bacterial kidney disease (BKD) in chinook could be influenced by various combinations of lipid, iodine, and fluorine concentrations in the diet. Although the study is still underway, results obtained to date indicate that susceptibility to BKD is not influenced by any of the factors tested. *(Contact: T. Evelyn.)*

Another BKD study is assessing the impact of the disease and treatment of smolts, prior to release, on the ocean survival of hatchery-reared chinook and coho salmon from Robertson Creek and Capilano hatcheries. Survival of groups of coded-wire tagged anti-BKD treated and non-treated fish released in spring 1987 will be

monitored in the fishery and in adult returns to the hatcheries. *(Contact: T. Evelyn.)*

Studies on infectious hematopoietic necrosis (IHN) virus in sockeye fry in the Babine Lake system confirmed that significant mortalities may occur within a few days of fry leaving the spawning channels. Mortalities in emerging fry held for four-day periods throughout the fry migration ranged from 12% to 68% in spawning channels and from 3% to 26% in the adjacent river. These fry were derived from spawners with a high prevalence of IHN virus. In contrast, in the Nadina spawning channels, both the spawning adults and fry were free of IHN virus, and no mortalities occurred among fry held for four days following their emergence from the gravel. Results suggest that spawners play an important role in the cycling of the virus and spawned-out fish should be removed from channels to reduce the IHN infectious load. *(Contact: G. Traxler.)*

An IHN epizootic occurred in a feral population of kokanee in Cameron Lake, Vancouver Island. This was the first record of the disease in Cameron Lake. As observed with kokanee in other lakes, the losses occurred only in two-year-old fish. *(Contact: G. Traxler.)*

Fish Disease Control

During 1987/88, fish disease control activities centred on quarantine and health monitoring of imported Atlantic salmon, investigations into the occurrence of disease in wild salmonids, provision of a diagnostic service to private fish farms, administration of the Fish Health Protection Regulations, assistance to the Region's Transplant Committee, assistance in the development of regional fish health policies, and provision of a comprehensive diagnostic service to federal fish culture operations. These activities were coordinated into five main program projects. *(Contact: G. Hoskins.)*

Monitoring of Atlantic salmon importations involved eggs from Scotland and the U.S.A. All eggs entering B.C. and all fish subsequently hatching from the eggs were required to undergo one year of quarantine. From 1985 to 1988, five and one half million Atlantic salmon eggs, mainly from Scotland, were imported into B.C.

Seventeen disease surveys of wild fish were carried out. In Pacific salmon, following spawning, many of the disease agents contracted during the life of the fish express themselves as gross infections and are therefore readily detected. For this reason, much of the survey work was conducted in the fall using spent migrant adults.

Assisting private fish farmers with fish health problems remains a major activity of

the Program. Many of the cases investigated involved seapen cultured coho and chinook. The health problems in tested fish frequently centred around gill disease, algal blooms, bacterial kidney disease, vibriosis or adverse environmental conditions. The number of requests for assistance from the private sector farmers is decreasing and is expected to continue to do so as private laboratories develop the necessary expertise in fish health.

As fish culture expertise and disease awareness has developed within B.C., the number and severity of the fish health problems encountered in DFO facilities have decreased. However, several fish health problems remain. One of the most difficult diseases to combat remains proliferative kidney disease at the Puntledge River project, where high mid-summer water temperatures favour the disease.

A joint federal/provincial policy, similar to that for importing Atlantic salmon, has been proposed for importing Pacific salmon into British Columbia.

A number of trout farms were certified for export of fish under the Canadian Fish Health Protection Regulations.

Shellfish Diseases

Studies continued on clams, oysters, mussels, scallops, prawns, and shrimps. In a survey of oysters and Manila clams from a number of localities in British Columbia, two new diseases were identified in oysters, one caused by a *Cytophaga*-like bacterium that erodes the hinge ligament and the other by a fungus that produces gross shell deformities. Additional data were obtained on the distribution of Denman Island oyster disease (caused by a microcell) and a fatal inflammatory disease of oysters caused by an actinomycete bacterium. A formalin treatment was devised to treat the *Cytophaga*-like disease in juvenile oysters in a culture facility.

Summer mortalities of mussels, a common phenomenon in certain localities in B.C., are not disease-related. No correlation was found between the occurrence of a neoplastic condition in mussels and the summer mortality.

An atlas of the histology of scallop larvae is being prepared to enable the recognition of diseased tissues in dying cultured larvae.

Field and laboratory studies on the Rhizocephalan parasite *(Sylon)* of shrimp and prawns have indicated that the parasite has a disjunct distribution in B.C. shrimp. There is no seasonal difference in infection, and the same species of *Sylon* appears to occur on four species of shrimp. All ages of the prawn *Pandalus platyceros* are

susceptible to infection, and castration of the host depends upon when the infection was acquired. Survival of wild prawns may be affected by the parasite. *(Contact: S. Bower.)*

Parasitology

Further work using parasites as naturally occurring biological tags confirmed results reported last year that sea mount populations of sablefish are distinct from those living on the continental slope. *(Contact: Z. Kabata.)*

In a cooperative project with the Salmon Production Section, the stock composition and migratory route of juvenile sockeye migrating out of the Strait of Georgia was estimated from stock variations in parasite assemblages, using a maximum likelihood stock composition model. Results showed that most sockeye smolts migrate northward either directly along the mainland coast or by first crossing the Strait of Georgia towards Vancouver Island and then moving northward diagonally across the Strait to join the smolts migrating along the mainland shore. There was no stock specific route selection. Parasites were also used to identify the stock composition of sockeye taken in the Indian food fishery at Lillooet in the Fraser River. *(Contact: L. Margolis.)*

A recent discovery of *Kudoa*, a myxozoan parasite, in the heart of a coho salmon, prompted investigation of the prevalence of this parasite among salmonid species. Examination disclosed that coho, chinook, pink salmon and steelhead trout are infected. Sockeye and chum are free of *Kudoa*. These findings raise the possibility that *Kudoa* might have an impact on the salmon survival at sea. *(Contact: Z. Kabata.)*

A three-year study on the impact of the protozoan parasite *Ceratomyxa shasta* on seaward migrating juvenile chinook salmon in the Fraser River was completed. Results confirmed previous findings and suggested that *Ceratomyxa* is not a major factor in mortality of juvenile Fraser River chinook. *(Contact: L. Margolis.)*

Fish Culture Research

This section conducts studies in a wide range of disciplines related to commercial aquaculture and resource enhancement. Research areas include nutrition, smoltification, incubation and water quality, time and size at release, aquaculture biotechnology, reproduction biotechnology, genetics and broodstock evaluation. The

last four of these research programs comprise the Centre of Disciplinary Expertise (CODE) for biotechnology and genetics in aquaculture.

In addition to its research and development program, the section is involved in technology transfer to the aquaculture industry and responds to a wide range of enquiries on aquaculture technologies. *(Contact: E.M. Donaldson.)*

Nutrition

A collaborative study with the Salmon Mariculture Program revealed major differences in susceptibility of post-juvenile coho to bacterial kidney disease (BKD) in relation to diet treatment. A Finnish silage-based diet resulted in excellent growth and resistance to BKD relative to that noted for coho fed another silage-based diet (only dry mix differed from that in Finnish diet) and two leading commercial dry diets.

A study of chinook broodstock diets has shown that the linolenic series of fatty acids are essential in the diet of maturing chinook salmon, and that dietary lipid composition can influence egg size. A second broodstock nutrition study, aimed at improving egg survival, assessed the effect of dietary protein level and lipid composition on the reproductive viability of coho in seawater. These studies, aimed at improving egg survival and consequently the number of high quality smolts available for the aquaculture industry are essential as demand (25 - 30 million chinook) far exceeds supply (13 - 18 million chinook eggs)

A study with the Fish Health Section is presently underway to determine whether dietary lipid oxidation and iodine and fluorine content influence susceptibility of post-juvenile chinook in seawater to infectious disease agents (BKD and furunculosis). Dietary treatment appears to have influenced susceptibility of chinook to furunculosis, although this requires confirmation, and the BKD challenge portion of the study is still in progress.

Preliminary findings from an M.Sc. project on the dietary protein requirement of post-juvenile chinook in seawater suggest that the protein requirement approximates 44% of dietary dry matter (estimated metabolizable energy content = 4100 kcal/kg). In this study, plasma growth hormone and glucose levels were inversely related to dietary protein content, whereas plasma insulin levels tended to show a direct relationship to the level of protein in the diet.

Preliminary work was initiated on the quality of farmed versus wild coho salmon, and carbohydrate utilization in chinook in seawater. Further, in an NSERC Strategic

study with Dr. J.G. Eales in Winnipeg, it was noted that dietary thiiodothyronine supplementation enabled rainbow trout, at 6 deg. C, on a high carbohydrate diet, to attain growth approaching that of trout on a high lipid and low carbohydrate diet. This finding has important economical implications when culturing salmonids at low water temperatures. *(Contact: D.A. Higgs.)*

Salmonid Mariculture

A laboratory experiment demonstrated that juvenile chinook from the Quesnel River Hatchery are prevented from becoming zero-age smolts when exposed to long photoperiods at the time of first feeding. This is unlike coastal chinook which are able to smoltify after either long or short photoperiod exposure. Grilse from the first year-class of Atlantic salmon reared at the Experimental Fish Farm were spawned, the eggs reared to hatch, and feeding of the fry initiated successfully. A feeding trial demonstrated that moist diets based on hake silage are highly palatable and support good growth of coho salmon. *(Contact: W.C. Clarke.)*

Incubation and Water Quality

Incubation of sablefish eggs (from captive and wild adults) continued as part of the larger collaborative sablefish culture project. Egg survival to hatching of 40% was achieved by employing rotating cylindrical containers. Additional tests on egg and larval tolerance to lower (29 ppt) salinity levels indicated that production of large numbers of larvae is feasible.

Combined effects of various temperature and water exposure periods were tested on chinook salmon egg survival in moist air. At temperatures of 10 and 12 deg. C eggs develop normally, even if only rinsed with water once every 24 hours. At higher temperatures, significant mortality occurs both in water and in moist air. Tests are continuing which will determine changes in salmon egg tolerance to high temperature and exposure to dewatering at various stages of development.

A microcomputer program was developed for predicting embryonic development in Pacific salmon and steelhead trout. This program (for use with PC-compatible microcomputers) calculates development time to 23 egg-stages as well as hatching and emergence times at various temperatures. *(Contact: J. Jensen.)*

Stress and Histopathology

In a collaborative second study with Dr. C. Clarke, tissue samples were collected to assess the effect of sterilization on growth and smolting of coho salmon. A major review on Stress and Tolerance for a new volume on the Physiological Ecology of Pacific Salmon was completed. *(Contact: J.R. McBride.)*

Time and Size

Tagged chinook salmon were again recovered at Quinsam Hatchery from releases made in 1982 and 1983. The 1982 study is completed with recovery of six-year-olds, and a similar recovery program in 1988 will complete the 1983 study. Effects of size at release varied between studies. In the first, adult returns increased sharply with increasing size for the earliest (May 5) release, with little effect of size in the remaining three releases. In the second, returns increased sharply with increasing size for the first three releases. Both studies indicate that for juveniles of a given size earlier release will produce higher returns. No optimum combination of time and size has been determined in either study; however, using results obtained it is possible to examine alternate release strategies.

Tagged chum salmon were recovered at Conuma Hatchery. These are the first returns (three-year-olds) from releases made in 1985. Very strong effects of both time and size at release were evident, with the highest returns resulting from the largest juveniles in each of the four releases. Returns from the second release (April 16) were approximately four times those of any other release. A similar recovery program will be conducted in 1988. A small number of five-year-olds may return in 1989, completing the study. *(Contact: B. Morley.)*

CODE for Biotechnology and Genetics in Aquaculture

Reproduction Biotechnology

Ninety-one three- and four-year-old phenotypic male genotypic female chinook males were used in 1987 to produce monosex sperm for the aquaculture industry. Total volume of sperm collected was 12.1 litres. Milt was distributed to 15 private

commercial hatcheries in 2,422 aliquots. Estimates are that close to five million all-female smolts may have been produced.

A comprehensive study on the application of sex control techniques at commercial mariculture facilities continued during 1987/88.

Pilot tests on sex inversion (direct feminization and masculinization) and sterilization of coho and chinook stocks were conducted at 15 salmon farms in B.C. Under an Experimental Study Certificate issued to BSB by Health and Welfare Canada, about two million chinook and coho were treated by estrogen administration in 1987 at nine different farms. Preliminary data show variable results at different locations with a mean of 67% and 88% females produced in chinook and coho alevins respectively. These results are less successful than previous laboratory experimental trials at 10 deg. C which produced, at the doses recommended for use at the commercial hatcheries, 82% females in chinook and 97% females in coho.

To improve treatment procedures, further laboratory studies were conducted using estrogen and androgens in coho alevins, allowing definition of steroid sensitivity peaks in early ontogeny. Efforts to originate a line of all-female sperm production using several groups of salmon continued.

Thirteen commercial hatcheries participating in experimental studies in 1987 produced over 7.5 million sterile coho. Histological analysis of samples indicate that a high degree of sterilization was achieved at most locations (mean 95% success rate).

A study on the hormonal sterilization of chinook salmon is underway. Histological analysis of samples prior to seawater transfer showed a high percentage of sterile fish in groups treated with 40 to 80 mg of 17 - methyltestosterone in the diet for 8 to 12 weeks. Further inspection of selected groups after almost two years of netpen rearing showed permanence of the sterile condition and an associated average 15% reduction in mean weight. Performance of sterile and control fish will continue to be monitored by following growth and sexual condition of fish individually marked with passive integrated transponder (PIT) tags.

Two hundred thousand all-female chinook smolts were released in June 1987 from the Capilano Hatchery in a continuing effort to enhance sub-optimal Capilano River chinook stocks by increasing the proportion of females in future hatchery escapements.

Sablefish captive since early fall 1987, were successfully induced to spawn using DAla^{6}-LHRH-Pro^{9}-ethylamide, a synthetic hypothalamic gonadotropin releasing hormone nonapeptide. Preliminary evaluation to determine the effect of low water temperature and/or darkness suggests that no significant differences in spawning

response could be observed. Partial ovulation and irregular egg quality were observed in several spawning females. Other fish collected from the wild in January 1988 were also injected and successfully ovulated. *(Contact: I.I. Solar.)*

Biotechnology

Research in this program is focused on chromosome set manipulation and the application of biologically active peptides and proteins in fish culture.

In studies on chromosome set manipulation, field trials on a semi-commercial scale have been initiated on the production of triploid Pacific salmon. The technique of gynogenesis has been utilized in combination with steroidal masculinization for the first time to reduce the time required to produce monosex female sperm from two generations to one generation.

Growth enhancement by manipulating the endocrine system in cultured Pacific salmon continues. A monoclonal antibody directed against the growth inhibitor, somatostatin, has been tested in further growth studies and found to have a prolonged clearance time. The purification of salmon growth hormone from coho pituitaries is nearing completion. This material will be used to establish a radioimmunoassay (RIA) which will enable monitoring of the physiological response to anti-somatostatin treatment, and studies on the physiology of growth hormone in salmon. An immersion technique has been tested as a practical alternative for administering recombinant somatotropin, a potent growth enhancer, to juvenile salmon.

Oral administration of both salmon gonadotropin and vitellogenin to chinook and coho resulted in the rapid appearance of these proteins within the circulation. Thus, the salmonid gut demonstrates a capacity to absorb intact, orally-applied proteins. Blood clearance studies showed these high molecular weight proteins to be remarkably stable over time. Tissue examinations revealed that the liver and kidney were central organs of protein accumulation and metabolism.

Comparison of the time-course of absorption (plasma profiles) of orally and rectally delivered recombinant bovine somatotropin (rbGH) showed that rectal administration resulted in significant increases in plasma rbGH presence as opposed to orally-treated fish. This provides conclusive evidence for the effect of gastric and pancreatic secretions on intact peptide and protein absorption.

The quantitative assessment of gastrointestinal absorption of any pharmaceutical agent requires that data is available on hepatic portal vein blood flow, and that

arterial and venous blood may be sampled simultaneously. To this end, techniques designed to cannulate the hepatic portal vein and dorsal aorta of free-swimming salmonids have been developed. *(Contact: E.M. Donaldson.)*

Salmon Genetics

A pilot-scale selective breeding program to improve saltwater growth and survival in coho salmon under pen culture conditions was initiated. Over 200 families of coho from three stocks (Robertson Creek, Quinsam River, Kitimat River) were individually reared and monitored for growth and survival in fresh water at Rosewall Creek Hatchery. All of the experimental fish were marked to the family level with coded-wire tags. In addition, 10% of the fish were injected with PIT (passive integrated transponder) tags for individual identification. Fish from all families will be distributed for saltwater rearing and performance monitoring to the PBS farm site and a commercial farm site. Gametes from fish exhibiting superior performance will be collected in the autumn of 1989.

A genetic analysis of susceptibility to BKD within and among five strains of coho salmon revealed no difference among strains in mean time-to-death after inoculation with the BKD pathogen. However, within strains, there was significant variation among families in time to 25 per cent mortality. This indicated that selective breeding to reduce BKD susceptibility within a domesticated strain of coho would be successful. Further experiments to determine the genetic control of BKD susceptibility in Pacific salmon are underway. *(Contact: R.E. Withler.)*

Chinook Juvenile Broodstock Comparison

This federal-provincial study began in 1985 with delivery of marked families of six chinook strains to four commercial salmon farms and the PBS experimental farm. In 1987-88, sampling continued to show that growth and survival differed significantly among strains and among rearing sites. Preliminary analysis of growth data showed a significant interaction between strain and site, although site-environment clearly had the strongest influence on mean weights. Growth performance on average exceeded previous records with earlier diet formulas by a factor of up to two. Three-year-old fish maturing during this year ranged from 2% to 60% of surviving fish; of the two North Coast wild strains, the Kalum strain averaged 5% to 10% mature, while the Atnarko strain averaged 20% to 30% mature. The Quinsam strain

did not produce any mature females. The Sunshine Coast site averaged a considerably higher percentage of mature fish than any other site, while the North Coast site recorded less than 0.5% female spawners, and the West Coast site averaged close to double the egg-production per female over any other site. Analysis of these and other differences is underway, and the study is continuing in 1988-89. *(Contact: H. Kreiberg.)*

Salmon Habitat Research

Research conducted in this section determines the salmon productivity of fresh water, estuarine, and marine habitats for stock and habitat management. Research data are provided on the impact of industrial activity, including forestry, transportation, wastewater discharge, hydroelectric generation, and agricultural sectors on the capacity of the regional habitat base to produce salmon. Research projects are conducted to define the utilization of habitats by fish and the dependence of fish stocks on specific habitat types.

In 1987/88, a national workshop was hosted which dealt with quantification of habitat in relationship to salmonid stocks. Papers from the workshop were reviewed and edited in preparation for publication as a Special Publication of Canadian Fisheries and Aquatic Sciences. Considerable effort was also expended on assisting habitat managers at the regional and national level with implementation plans for the "no net loss of productive capacity" habitat policy.

Fraser River Program

Overwintering Juvenile Chinook and Migration

Sampling programs continued to expand the database of the Fraser basin capacity to rear chinook salmon. Trapping of juvenile chinook at the mouth of the Nicola River was conducted until July 1987, showing that chinook outplanted in September 1986 successfully overwintered in the Nicola. Surveys for overwintering chinook were conducted in November, just prior to freeze up, at Quesnel River, Slim Creek, Salmon River (Shuswap system), and Eagle River. Results showed that chinook were overwintering in Slim Creek and Quesnel River, while at Quesnel it was found that

hatchery-reared chinook released in the fall had moved into Quesnel Lake. Samples of overwintering juvenile chinook were obtained near pulp mills at Quesnel and Prince George on the mainstem Fraser and tissues were analysed by scientists in the Physical-Chemical Sciences Branch. Body burdens of chlorinated organics, including dioxins, were significantly elevated at stations influenced by the mills, in part due to prolonged residency during the overwintering phase when juvenile chinook reside in substrate. The downstream boundary of overwintering habitat in the Fraser was found to be in the vicinity of Agassiz. This is probably related to the distribution of suitable cobble substrate on the river shoreline. Results suggest that the entire mainstem of the Fraser River, from Prince George to Agassiz, is used as overwintering habitat. A surface trawling program initiated at New Westminster verified that chinook were not moving to the estuary in the fall, as had been earlier hypothesized. *(Contact: C.D. Levings.)*

The abundance of several species of fish were monitored monthly or bimonthly for one year at sites near Agassiz and in the north and main arm of the Fraser River. In addition to all salmonid species many non-salmonid species were also captured, including a variety of sculpins, flounders and shiners. Size analyses of captured chinook show they pass through the Agassiz region quickly, spending a month or more at sites in the lower estuary, leaving by early September. Starry flounder are found in the estuary throughout the year, but are particularly abundant from April to September. Adults (75+ mm) are caught from April to June while young-of-the-year (15+ mm) appear in June and remain abundant until October. Prickly sculpin adults (35-55 mm) were caught from April to July while young-of-the-year (30-40 mm) appeared in August and remained until October. These data will assist in describing residency times of Fraser River fishes and allow comparison of the degree to which different habitat types are used.
(Contact: J.S. Macdonald.)

Pollution and Reviews

Fisheries and Biological Sciences are represented on the Regional Ocean Dumping Advisory Committee (RODAC) for the Pacific/Yukon Region. RODAC administers the Ocean Dumping Control Act in the Region, reviewing and recommending action on about 60 ocean dumping applications annually. During 1987-88, advice was also provided on plastic debris in the oceans and on incineration at sea.

RODAC develops and executes a research program related to national and regional ocean dumping problems, with financial support from the Ocean Dumping Control Act Research Fund. With this support, a study of amphipod bioassays on sediments along the B.C. coast containing heavy metals and organic contaminants was

conducted during 1987/88. The three most toxic sites were in the Vancouver area: Pacific Coast Terminals (Port Moody), Vancouver Wharves (on the north shore of Burrard Inlet, just east of the First Narrows), and False Creek. *(Contact: M. Waldichuk.)*

Sockeye Habitat

A knowledge of the carrying capacity of sockeye habitats within the Fraser River and its tributaries and lakes is key to setting realistic goals for future expansion of the sockeye resource. An understanding of the critical habitat provides insight into options available for implementing a strategy for growth of the sockeye resource.

An estimate of the carrying capacity of the critical spawning and rearing habitat in 80 spawning streams and 22 lakes was derived from estimates of available habitat and the habitat-stock relationships, comparing habitat utilization with fry and smolt production.

Total spawning-incubation habitat was estimated at 5.3 M^2, while rearing habitat was estimated at 2,400 km^2. The relationship between available spawning habitat, number of spawners, discharge, and fry production was examined in four systems in different biogeoclimatic zones, while data from three lakes was used to examine carrying capacity of the rearing habitat.

The relationships derived were considered representative of their respective biogeoclimatic zone and were then used to estimate production from habitats within various biogeoclimatic zones.

The sum of the critical habitats gives a carrying capacity estimate of 11.4 M spawners in the Fraser River system. It was estimated that this could produce 28.8 M sockeye based on a conservative return per spawner of 2.25. These data were used to develop recommendations for the Fraser River Sockeye Task Force, established by the Fraser River Division Area Planning Committee. *(Contact: I. Williams.)*

Contaminant Interactions

Juvenile chinook salmon overwinter in the Fraser River where they are exposed to minimum dilutions of industrial and municipal contaminants. Bioconcentration of

chlorophenols by juvenile chinook was studied at 0.7° C at the Cultus Lake Laboratory using Fraser River water to simulate winter conditions in the upper Fraser River. Although low temperatures minimized metabolic activity and food was not offered, test fish bioconcentrated significant amounts of chlorophenols from the ambient test solutions. Pentachlorophenol was preferentially bioconcentrated over other chlorophenols. In addition, test and control fish bioconcentrated chloroguaiacols from the Fraser River water. The chloroguaiacols would have been discharged in the Fraser River more than 500 km upstream of the place where water was collected for laboratory exposure tests. Chlorophenol body burdens of salmonids derived from field measurements, from experimental exposures conducted at Cultus Lake Laboratory, and from the scientific literature, yielded a log-log relationship with chlorophenol content of ambient water. This relationship appears to have value as a monitoring tool.

Variable suspended sediment loads are common to many rivers used by Pacific salmon. Pacific salmon, particularly juvenile Fraser River chinook salmon, may inhabit dilution zones where ammonia and suspended solids mix. To address the interactions of ammonia and suspended solids, tests were conducted to define the effect of suspended solids on toxicity of ammonia. Results indicate that mixtures of ammonia and suspended sediments are more toxic to juvenile chinook than either contaminant alone. Studies of suspended sediment alone revealed that juvenile coho were least tolerant in acute tests at 2° and 17° C and most tolerant in the range 7° to 10° C. Sublethal tests revealed increased cough response, serum glucose elevation and surfacing behavior at typical environmental levels of suspended sediments.

A review of proposed Yukon Placer Mining Effluent Standards was conducted. Analysis of operations indicated that suspended solids would exceed 150 mg L more than half the time when effluents met the proposed standard of 0.2 mL settleable solids. The review concluded that an effluent standard equal to 0.2 mL settleable solids could lead to significant impact on fish habitat. The review recommended adoption of standards based on suspended solids as turbidity since there is evidence that such standards can provide satisfactory levels of protection.

The Contaminants Interaction group collaborated with the Department of Chemistry, University of British Columbia, on aquatic toxicity tests of a new type of wood preservative. Test results indicated implications for toxicity.

Expert reports on the potential effects on gas supersaturation of proposed water flow regimes in the Nechako River were prepared to assist the DFO Nechako Task Force to prepare for court. Expert reports submitted by Alcan were critiqued. Assistance was given to Department of Justice in preparation of technical testimony. *(Contact: J. Servizi.)*

Pollution and Toxicology

During 1987/88 efforts were directed towards ensuring that the new West Vancouver Laboratory's aquarium and water systems for fish maintenance and related research were suitable. In addition, publication of research results on salmon ecology and behaviour and the effects of placer (gold) mining sediment on Arctic grayling proceeded satisfactorily. World-wide scientific interest was expressed over the water column simulator (WCS) which enables mimicry of a variety of aquatic conditions (such as a vertically stratified estuary). Year round use was made possible by the installation an efficient temperature control system, and the use of computerized image analysis of time-lapse video recordings of experimental fish. Recent analyses have revealed a temporal change in the behaviour of juvenile chinook salmon in relation to salt water adaptation, and their response to dissolved oxygen depression. Experiments are underway to examine effects of toxic chemicals on salmonids via their ability to withstand predation. Further analyses substantiate the contention that juvenile salmon use degraded habitats due to innate behavioural traits, and in doing so may jeopardize their health and survival.

For the second consecutive year, lipid-rich eulachons were sampled in the Fraser River for quantitative information on the presence and relative areas of contamination by chlorinated organic compounds. The concentration of compounds (wood preservatives) in eulachons increased in relation to the distance the fish had travelled during their spawning migration from the mouth of the Fraser River.

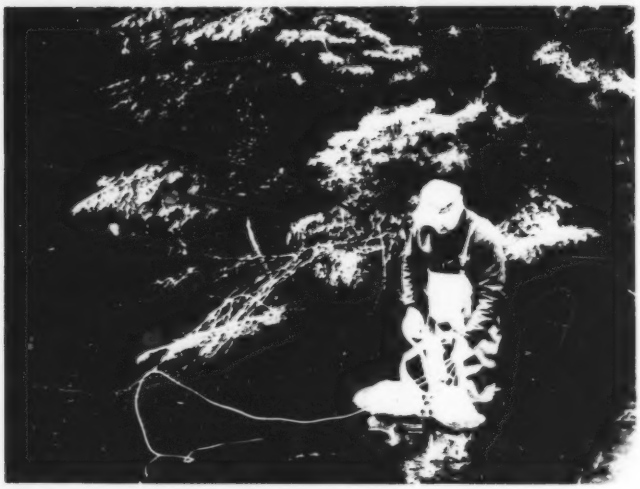
Advice was provided on the effects of hydrocarbons on aquatic resources, placer mining sediment, water quality criteria, dissolved oxygen and pulpmill pollution. *(Contact: I.K. Birtwell.)*

Fish Forestry Program

Synoptic Survey

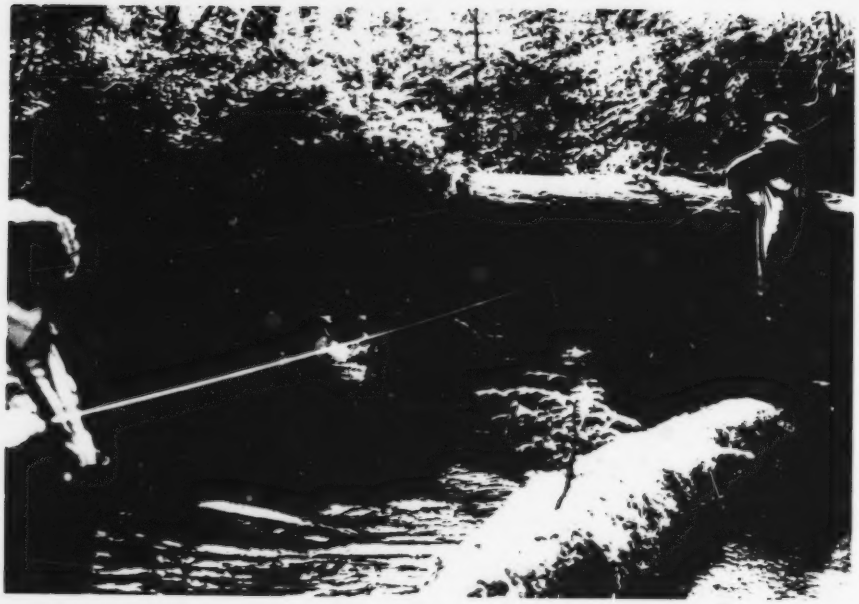
A synoptic survey was initiated to obtain a representative measure of the physical and biological condition of a stream channel relative to the age of the bordering riparian zone. Logging cut histories of 98 watersheds in Barkley and Clayoquot sounds on the west coast of Vancouver Island were combined with spawning escapement data to form the basis for identifying study streams. Five locations in each of 43 streams in these areas were sampled for stream rearing salmonids just

prior to smolt migration . At each location environmental features were noted, length and weight of all juvenile coho recorded and scales obtained for ageing.



Technician setting live traps for capturing juvenile salmonids

Juvenile coho are anesthetized, weighed and measured and released back to the stream.



Large organic debris, used by juvenile salmonids for cover was measured in all 48 test sites.

The data were combined with ground truthing to locate 48 study sites in 32 watersheds with differing logging histories (unlogged, recently logged to logged 100 years ago) and watershed sizes (1.5 to 275 km). Physical features of all study sites were surveyed and detailed maps produced including location and size of large organic debris (LOD), stream width, and bank integrity. Stream rearing salmonid populations utilizing these sites will be examined in detail in 1988/89 and the results compared with physical features of the sites and with their respective logging histories.

A cut history database was started in the B.C. interior. Approximately 100 streams in the Kamloops/Clearwater area are being examined for logging history and salmon escapements. This will provide insight into possible study sites for examining the effect of logging on stream salmonids in the interior where climate and geology vary widely from the coastal areas. *(Contact: I. Williams.)*

Experimental designs associated with fish-forestry interaction research frequently

require coho population abundance estimates for a large number of coastal watersheds. Five coastal watersheds, each with a smolt counting fence for definitive population estimates, were sampled with Gee traps and electrofishing gear set in randomly selected pool, riffle and run habitats. Coho were found more frequently in pools in the lower reaches of each stream. Population estimates for each stream, expanded from electrofishing observations from each site, were at least an order of magnitude lower than fence counts. Apparently electrofishing apparatus operates inefficiently under winter conditions. Electrofishing provided the best population estimates in small streams and in streams with high fish densities but estimates never exceeded 17% of the fence counts. Future research will investigate the importance of habitat cover, rather than overall habitat area as a predictor of fish abundance. *(Contact: J.S. Macdonald.)*

Carnation Creek

The Carnation Creek study was initiated in 1970 to examine long term effects of logging on the watershed. Results from this multidisciplinary study have been key to establishing the new Coastal Fisheries and Forestry Guidelines.

Monitoring of the fry, September fingerling, smolt and adult salmonid populations in Carnation Creek is expected to continue to 1991. Data will be combined with physical and biological variables to examine the long term effects of logging. While different logging and silvicultural activities have different physical effects on the stream environment, whether these have positive or negative impacts on fish depends on the intensity of the activity, species of fish and their life stage. Interannual variability among adult salmon populations returning to their natal streams ranges up to 10 fold. Therefore, a long term database and an understanding of ecosystem processes at all life history stages of the fish are required to separate logging impacts from natural variability. The influences of forest harvesting on the average numbers of adult salmon returning to Carnation Creek are small (-5% to -24%), but tend to double the interannual variability of fish production.

Results of a multidisciplinary herbicide study conducted at Carnation Creek were presented at a workshop in 1988 attended by 300 people from science, operations and industry. Proceedings will be published during 1988 in the Canada/ British Columbia Forest Resource Development Agreement Report series. In addition, a bibliography of approximately 145 publications from Carnation Creek was assembled and will be available in 1988.

Following fire damage, the camp at Carnation Creek was rebuilt largely through a contribution from the Council of Forest Industries. *(Contact: C. Scrivener.)*

Aquaculture Inlets Program

This year, preliminary studies were conducted to examine the effect of salmon net pen wastes on wild fish habitat. Sechelt Inlet, a relatively poorly flushed fjord, was examined. Benthic effects, including the development of Beggiatoa (bacterial mat), were observed at farms within Sechelt Inlet. Analyses of rockfish *(Sebastes maliger)* tissue from fish collected at farm sites and a reference area showed that higher concentrations of chlorinated organics were present in rockfish from the farm site. *(Contacts: C.D. Levings and I.K. Birtwell.)*

Fish Habitat Quantification Program

In 1987, the Department of Fisheries and Oceans was involved in major litigation over streamflows in the Nechako River. Research into distribution of juvenile chinook and their habitat requirements in various locations within the river was documented. A report was prepared on these and other findings from previous field seasons. In preparation for trial, these findings, along with many other studies on regulated rivers, were reviewed, and a substantial Expert Report was prepared as evidence. This litigation was successfully concluded with an out-of-court settlement in September 1987.

In order to advise habitat managers on appropriate tools to implement the National No-Net-Loss Habitat Policy, new work on habitat assessment methodology began in 1987. PHABSIM, a popular U.S. Fish and Wildlife Service method was tested. To evaluate the method's accuracy, predictions of usable habitat from the method were compared to habitat actually used by Pacific salmon. Results are currently being analyzed. *(Contact: C. Shirvell)*

Coastal Fish Habitat Program

Extensive analyses were conducted on data from the Campbell River Estuary Program, a program to examine prospects for rehabilitation of estuarine fish habitat and techniques to determine habitat significance for chinook salmon survival. Returns from experimental releases indicate chinook exposed to the estuary in 1983 and 1984 survived best to catch and escapement. Survival rates for fish exposed to the estuary in 1985 were not significantly different when compared to fish released directly to marine habitats. Results indicated an increase in marine survival for the latter group. Results of the five-year monitoring program for rehabilitated estuarine

habitat showed chum and wild chinook fry consistently used the man-made islands especially close to the river channel. Abundance of fish food items varied between taxa. Insects, annelid worms, one taxa of amphipod and meiofauna (harpacticoids) colonized the islands fastest. In the Fraser River estuary, estimates of insect productivity from floating emergent traps were found to be a useful proxy measurement for "productive capacity" of estuarine fish habitat.
(Contacts: C.D. Levings and C.D. McAllister.)

Science and Survey Support

Marine Division

Marine Division provided ship, launch and depot support for the science and hydrographic programs of IOS, the fisheries research conducted by PBS, and research by other federal agencies and universities.

In 1987, the formal consolidation of the regional ships' management at IOS was completed, with the amalgamation of science, survey and enforcement vessels resulting in a fleet size of over forty ships.

FRV CALIGUS (home port, PBS; 17 metres overall; gross tonnage 41.36)

The FRV CALIGUS spent 162 days at sea in 1987/88, steaming 5,100 nautical miles in B.C. coastal waters. The ship provided support for shellfish, groundfish and salmon research.

CSS PARIZEAU (home port, IOS; 64.3 metres overall; gross tonnage 1314)

In the early part of 1987/88, the CSS PARIZEAU completed her refit and conversion to Unmanned Machinery Spaces. After sea trials, the PARIZEAU steamed 25,000 nautical miles in 253 days in support of Ocean Physics, Ocean Chemistry, and Tides and Currents for IOS. She also supported work from the Pacific Geoscience Centre and the Royal British Columbia Museum. The PARIZEAU also provided Search and Rescue (SAR) support to the herring fishery in March 1988.

CSS RICHARDSON (home port, IOS; 19.8 metres overall; gross tonnage 59)

The CSS RICHARDSON continued her hydrographic survey work in Cumshewa Inlet (Queen Charlotte Islands). In the later part of the year she was engaged in SAR duties with the herring fishery off northern Vancouver Island.

FRV W.E. RICKER (home port, PBS; 58 metres overall; gross tonnage 1105.52)

The W.E. RICKER steamed over 24,000 nautical miles in 169 operational days. Activities included work on the high seas between North America and Hawaii, and research on sablefish, hake, herring and salmon species.

CSS JOHN P. TULLY (home port, IOS; 69 metres overall; gross tonnage 2199)

The JOHN P. TULLY steamed over 20,000 nautical miles in 263 days with the major cruise being in support of science activities in the Beaufort Sea from July to October. She was also used by PGC in studies of the Juan de Fuca Ridge, and for the B.C. Museum sample collection survey off northern Vancouver Island.

CSS VECTOR (home port, IOS; 39.6 metres overall; gross tonnage 516)

The CSS VECTOR sailed 312 days, covering 13,752 nautical miles in support of scientists from IOS (Ocean Physics, Ocean Chemistry, Tides and Currents, Ocean Ecology), PBS and the Environmental Protection Service.

Submersible PISCES IV (home port, IOS; 6.1 metres overall; gross tonnage 12)

Although, the PISCES IV did not undertake any diving activities in the past year, the vehicle was maintained for possible emergency use. The PISCES crew was heavily involved in training and preparations with the ROV for deep water trials off Bermuda.

Barges PENDER and L. PACIFICA (home port, IOS)

The PENDER spent the summer months in support of hydrographic activities in the Tofino area of Vancouver Island. The L. PACIFICA was involved in similar duties in Vancouver Harbour.

Deck Machinery

Deck Machinery staff continued to provide maintenance and support for winches and cranes aboard various ships. The duties of the staff have expanded to cover the larger number of vessels being processed through the ICS Depot facilities.

Depot Workshops

The work of the Depot workshops continues to grow, as the fleet amalgamation is completed. Over 1,200 work requests were received.

Computing

Pacific Biological Station

Major highlights revolved around increases in demand for central computer services. The transfer and installation of a VAX 11/785 from regional headquarters was completed in February, 1988. The effect was an immediate increase in availability of central systems, the replacement of obsolete disk drives, and better system performance. A DECNET/Ethernet link between the VAX 11/785 and the PBS Microvax II was completed late in the year. Approval was sought and obtained for the replacement of the VAX 11/785 with three Microvax 3500 supermicrocomputers during 1988/89.

In conjunction with IOS Scientific Computing, draft microcomputer software and hardware standards and guidelines were developed, as well as a strategy document to act as a framework for the development and use of informatics technology in the Region. Microcomputer acquisition policies were modified to allow easier access. Networking and acquisition plans have been adjusted in anticipation of increased microcomputer acquisitions.

Software enhancements were made to the Mixed Stock Fishery model, the Fish Health DataBase was transferred from IOS/System 2000 and redeveloped on the PBS VAX, and Mark Recovery database usage increased with major revisions made to the user interface system. At the invitation of the University of Umea, Sweden, a PBS representative travelled to Sweden to install the PBS Response Surface package on their system.

Reorganization of EDP in the Pacific Region was completed with the reassignment of PBS EDP staff to Biological Sciences Branch.

Institute of Ocean Sciences

Major highlights revolved around changes to the Central Computer Systems. The Sperry computer lease was terminated as planned. Acquisition and installation of

the Oracle database management system on an up-graded micro-VAX computer enabled completion of the conversion of essential programs and data files.

The VAX 785 was upgraded by doubling the on-line disk storage and adding a third mag tape drive. Installation of Ethernet and DECnet enabled high speed data transfers between IOS computers. Enhancements to system software continued, particularly in the graphics area. Increasing use was made of animation (movies) to display the results of current analyses and theoretical ocean models. The VAX-785 became heavily used over the year, averaging 69 per cent utilization of all available CPU cycles (reaching a peak of 86 per cent in August).

Approval was obtained to replace the FPS Array Processor by a modern mini-supercomputer or attached processor. The DFO will lease the recently purchased Alliant FX/4 from DSS over five years. The FX/4 will process most of the computationally intensive ocean modelling workload in-house. Usage of the AES Cray X/MP at Dorval for this purpose exceeded 275 hours in 1987/88, but data communications were difficult and ongoing access is uncertain.

A review of scientific computing organization and support was conducted over the winter. Other initiatives included participation in a departmental data communications study focused on Science needs, development of a regional Science Technology Strategy, and Standards for hardware, software, and database development.

Communications

Communications activities in the science sector Pacific Region in 1987/88 included several "once in a lifetime" events in addition to on-going projects and response to requests for a large variety of information from both the general public and client groups.

The new West Vancouver Laboratory facility was officially opened by the Hon. Tom Siddon, Minister of Fisheries and Oceans in March, 1988. Following unveiling of a plaque and the offical opening ceremony, approximately 150 invited guests attended a reception and toured the building.

Ongoing tour programs at both the Pacific Biological Station and the Institute of Ocean Sciences continued to attract an increasing number of visitors, including school groups, tourists, service clubs and the general public. Both institutes provided tours for over 2000 people throughout the course of the year.

Communications staff participated in the planning and organization of the very successful IRIS-INPFC International Symposium on Recruitment and Errors in Stock Assessment Models held in conjunction with the 11th Annual Meeting of the International North Pacific Fisheries Commission in Vancouver, B.C.

Publications completed during the year included a new WVL brochure, the Science Review for 1986/87 and a variety of fact sheets including Aquaculture Updates. *(Contacts: K. Francis and K. Glover)*

Management Services

Pacific Biological Station

Management Services, PBS provides support to BSB in facilities management, purchasing, inventory control, vehicles, warehousing, publications, library, telecommunications equipment, records management and general office services.

All Divisional employees were affected by reassignments and the previous year's staff reductions.

The move into the new West Vancouver Laboratory was coordinated, trailers were removed, design shortcomings were identified, and change orders facilitated. Staff acted as consultants on service requirements.

The Offset Machine Operator position was reinstated, drafts of 117 reports were input, revisions to 570 reports were made and 53 reports were finalized for printing.

The building to store inflammable materials was completed. Critical areas of the salt water distribution system were upgraded from PVC to stainless steel.

Costs were paid to operate the International North Pacific Fisheries Commission HQ facility on the UBC campus. Remaining staff at the adjacent Vancouver Lab moved out and arrangements were made for the disposal of surplus equipment.

Records Management (including mail) moved into larger quarters. An improved mail distribution and security system was implemented. A leased electronic mailing system was purchased and a facsimile machine installed.

Purchasing staff took over the financial commitment function and received introductory training/information on the Purchasing/Contracting module of the new Financial Management System. Manual inventory records for new items purchased were maintained. Only a few computerized records were created, none were maintained nor were any physical checks carried out.

Library staff continued to transfer manual and paper applications to a microcomputer and were involved in software evaluation and the WAVES II (catalogue) database. *(Contact: B. Ross)*

Institute of Ocean Sciences

Management Services, IOS, provides support to approximately 500 personnel involved in the Science Sector and Marine Division. Support is provided in the areas of facilities management, purchasing, inventory control, vehicles, warehousing, Library services, telecommunications, records management and health, safety and security.

In 1986, it was decided to expand and upgrade the boat maintenance and haul-out facility at IOS as a result of the closing of the New Westminster marine station. A Treasury Board proposal has been prepared to allow for expansion of the present harbour including a breakwater, 122 lineal metres of floats, a 60 ton capacity haul-out pier and mobile travel lift, approach ramps and mechanical/electrical services at an estimated cost of $2.6 million over three years.

Purchasing staff took over the financial commitment function as the first step towards an improved Financial Management System. All Divisional Employees were affected by the re-organization. This task, combined with the increased purchasing activity resulting from integration of the marine fleets, has resulted in delays of approximately 3-5 days in processing. Delegation of local purchase orders

to IOS managers has helped handle the increased workload. The IOS inventory management system was converted to the Regional Headquarters system thus saving approximately $8.0 K in converting from Sperry to VAX.

In the Library, a Canon microfiche reader/printer was purchased to replace an obsolete read only model for public use. Work began late in the year to convert the Library catalogue data base from Sperry to VAX using the Oracle DBMS.
(Contact: J. Coldwell)

Appendix I

Publications 1987/88

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Appendix II

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Moonie, J.A.
Moorhouse, S.W.
Murty, T.S.; B.Sc., M.Sc. (Andhra), M.S., Ph.D. (Chicago)
Perkin, R.G.; B.A.Sc., M.Sc. (Brit. Col.)
Pite, H.; B.Sc. (Victoria), Ph.D. (Sydney)
Quay, L.
Richards, D.L.
Spearing, L.A.F.; B.Sc. (Brit. Col.)
Stickland, J.A.
Stucchi, D.J.; B.A.Sc. (York), M.Sc. (Dalhousie)
Sudar, R.B.; B.A.Sc. (Toronto)
Tabata, S.; B.A., M.A. (Brit. Col.), D.Sc. (Tokyo)
Teichrob, R.C.; Dip. (BCIT)
Thomson, R.E.; B.Sc., Ph.D. (Brit. Col.)
Topham, D.R.; D.L.C., D.C.A.E., Ph.D. (Loughborough)

Wallace, J.S.; Dip. (SAIT)
Warnes, T.M.; Dip. (Camosun)

** Left in 1987/88
*** On secondment from Nat. Hydrology Research Institute

Chemistry

Division Chief:

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps), Dip. Mar. Sc. (UNESCO), F.R.S. Chem. (U.K.), F.C.I.C.

Bellegay, R.D.; Dip. (NAIT), Assoc. Deg. in Oceanography (Shoreline Community College)
Cretney, W.J.; B.Sc., Ph.D. (Brit. Col.), F.C.I.C.
Henderson, J.G.
Johnson, W.K.; Dip. (BCIT)
Macdonald, D.M.; B.A.Sc. (Brit. Col.), Dip. (Camosun)
Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)
Mahood, H.[2]
McLaughlin, F.A.; B.Sc. (Victoria)
O'Brien, M.C.; B.Sc. (Alberta)
Paton, D.W.; B.Sc. (Brit. Col.)
Rogers, I.H.[2]; B.Sc. (Queen's, Belfast), M.Sc., Ph.D. (Brit. Col.)
Smith, G.L.; Dip. (NAIT)
Soutar, T.J.; Dip. (BCIT)
Thompson, J.A.J.; B.Sc. (McMaster), Ph.D. (Alberta), F.C.I.C.
Whitney, F.A.; B.Sc. (Brit. Col.)

2 West Vancouver Laboratory

Ocean Ecology

(see Biological Sciences)

Data Assessment

Division Chief:

Wilson, R.C.H.; B.Sc. (Simon Fraser), M.S. (Western Washington)

Giovando, L.F.; B.A., M.A., Ph.D. (Brit. Col.)
Smiley, B.D.; B.Sc., M.Sc. (Alberta)

Biological Sciences Branch

(Pacific Biological Station, Nanaimo, unless otherwise indicated)

Director:

Beamish, R.J.; Ph.D. (Toronto)

Thomson, J.A.; M.Sc. (McGill)
Steele, A.
Thompson, A.

Salmon Dynamics

Section Head (Acting):

Beacham, T.D.; B.Sc. Hons. (Manitoba), Ph.D. (Brit. Col.)

Bams, R.; B.Sc. Hons., Nat. Phil. Drs. (Leyden)
Barner, L.W.
Bernard, F.R.; Ph.D. (London)
Bigg, M.A.; Ph.D. (Brit. Col.)
Carter, E.W.; Dip. Forest Tech. (Alberta)
Cooke, K.D.; B.Sc. (Alberta)
Crabtree, D.
Dunbrack, R.; B.Sc., Ph.D. (Simon Fraser)*
Finnegan, B.[3]; B.Sc. (Victoria)
Gjernes, T.; B.Sc. (Victoria)
Groot, C.; B.Sc., M.Sc. (Amsterdam), Ph.D. (Leyden)
Hargreaves, N.B.; B.Sc. (Alberta), Ph.D. (Dalhousie)
Healey, M.; Ph.D. (Aberdeen)
Holtby, B.; B.Sc. (Carleton), Ph.D. (Toronto)
Hungar, R.M.; Fishing Master (Vancouver Marine College)
Irvine, J.; B.Sc. Hons., M.Sc. (Brit. Col.), Ph.D. (Otago)
Jordan, F.P.
Kadowaki, R.; B.Sc. (McGill)
Lebrasseur, R.J.; B.Sc., M.Sc. (Brit. Col.), Ph.D. (Glasgow)
Morris, J.; B.Sc. (McGill), M.Sc. (Concordia)
Mundie, H.; B.Sc. (Aberdeen), Ph.D. (London)
Murray, C.B.; B.Sc., M.Sc. (Brit. Col.)
Olesiuk, P.; B.Sc. (Manitoba)
Patten, B.; Dip. Fish. Cult. (Malaspina)
Sherry, M.
Simpson, K.S.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Tanasichuk, R.W.; B.Sc. Hons., M.Sc. (Alberta)
Ware, D.; B.Sc., Ph.D. (Brit. Col.)

* Left in 1987/1988

Salmon Production

Section Head (Acting):

Riddell, B.E.; B.Sc. (Guelph), Ph.D. (McGill)

Blackbourn, D.J.; B.Sc. (London), M.Sc. (Southampton), Ph.D. (Brit. Col.)
Cass, A.; B.Sc. (Brit. Col.)
Elder, C.A.
Enzenhofer, H.; Dip. (BCIT)6
Henderson, M.A.[1]; B.Sc. (Western), M.Sc. (Manitoba), Ph.D. (Brit. Col.)
Holmes, M.
Hudson, G.
Hume, J.[6]; B.Sc. (Brit. Col.)
Hyatt, K.D.; Ph.D. (Brit. Col.)
Kieser, R.; B.Sc. (Dalhousie), M.Sc. (New Brunswick), Ph.D. (Brit. Col.)
Kuhn, B.R.

Lapi, L.; B.Sc. (Wisconsin), M.Sc. (Washington)
MacIsaac, E.[2]; B.Sc. (Brit. Col.)
MacLellan, S.[6]; B.Sc. (New Brunswick)
Miki, I.
Morton, K.[6]; B.Sc. Hons. (Brit. Col.)
Mueller, C.[6]
Mulligan, T.J.; Ph.D. (Florida State)
Nagtegaal, D.; B.Sc. (Simon Fraser)
Rankin, P.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Rutherford, D.; B.Sc. (Brit. Col.)
Schnute, J.; Ph.D. (Stanford)
Serbic, G.; Dip. (BCIT), B.Sc. Hons. (Brit. Col.)
Shortreed, K.[2]; B.Sc. (Brit. Col.)
Starr, P.J.; B.A. (Yale), M.Sc. (Brit. Col.)
Steer, G.; B.Sc. (Brit. Col.)
Stockner, J.G.[2]; B.A. (Augustana), Ph.D. (Washington)
Traber, R.
Welch, D.; Ph.D. (Dalhousie)
Wilson, K.[1]; B.Sc. Hons., M.Sc. (Brit. Col.)
Wood, C.C.; B.Sc. (Simon Fraser), Ph.D. (Brit. Col.)

Ocean Ecology (Institute of Ocean Sciences)

Section Head:

Denman, K.D.; B.Sc. (Calgary), Ph.D. (Brit. Col.)

Brinkhurst, R.R.; B.Sc., Ph.D., D.Sc. (London)
Brown, R.M.; B.Sc. (Brit. Col.)
Forbes, J.R.; B.Sc. (Carleton), M.Sc. (Alberta)
Mackas, D.L.; B.S., M.S. (Washington), Ph.D. (Dalhousie)
Moore, D.F.; B.Sc. (McMaster)
Stone, M.

Fish Health and Parasitology

Section Head:

Margolis, L.; B.Sc., M.Sc., Ph.D. (McGill)

Baglo, P.
Bell, G.R.; B.S.A. (Brit. Col.), M.Sc. (Iowa State), Ph.D. (Western Ontario)*
Bower, S.M.; B.Sc., M.Sc., Ph.D. (Guelph)
Evelyn, T.P.T.; B.S.A., M.S.A. (Toronto), Ph.D. (Brit. Col.)
Hoskins, G.E.; R.T. (R.C.H.), B.Sc. (Alberta)
Kabata, Z.; B.Sc., Ph.D., D.Sc. (Aberdeen)
Ketcheson, J.E.; B.Sc. (Alberta)
Kieser, D.; B.Sc., M.Sc. (Dalhousie)
McDonald, T.E.; B.Sc.(Brit. Col.)
Meyer, G.R.; Dip. Fish Cult. Tech. (Malaspina)**
Mullen, K.E.; B.Sc. (Victoria)
Prosperi-Porta, G.; Dip. Chem. Analyst., Paolo Parodi Delfino, Collefero
Traxler, G.S.; B.Sc. (Washington)
Westby, C.M.; R.T. Can. Soc. Med. Technol. (BCIT)
Whitaker, D.J.; B.Sc. (Victoria)

* Left in 1987/1988
** Joined in 1987/1988

Groundfish

Section Head:

McFarlane, G.A.; B.Sc. (Winnipeg)

Adams, D.[5]; Dip. (BCIT)*
Burke, M.
Charles, K.
Chilton, D.
Cooper, J.
Davenport, D.
Fargo, J.; B.Sc. (Simon Fraser)
Foucher, R.P.; B.Sc. (Victoria)
Gillespie, D.; B.Sc. (Victoria)
Gillespie, G.E.; B.Sc. (Victoria)
Hand, C.M.; B.Sc. (Victoria)
Janz, S.; B.Sc. (Alberta)
Leaman, B.M.; B.Sc. (Simon Fraser), M.Sc., Ph.D. (Brit. Col.)
Leaman, J.E.*
MacLellan, S.; B.Sc. (Brit. Col.)
Mitton, W.
Nott, J.; B.A. (UCD)
Richards, L.J.; B.Sc. Hons. (Dalhousie), M.Sc., Ph.D. (Brit. Col.)
Rutherford, K.; B.Sc. (Victoria)
Saunders, M.; B.Sc. (Victoria)
Scarsbrook, R.
Selsby, J.*
Shaw, W.; B.Sc. (Victoria)
Smith, M.S.
Stanley, R.D.; B.Sc. Hons., M.Sc. (Brit. Col.)
Tyler, A.V.; B.A. (Pennsylvania), M.Sc., Ph.D. (Toronto)
Venables, N.L.
Westrheim, S.J.*
Winther, I.[3]; B.Sc. (Victoria)

* Left in 1987/1988

Herring

Section Head (Acting):

Haist, V.; B.Sc. (Brit. Col.)

Hay, D.E.; B.Sc. Hons., Ph.D. (Brit. Col.)
Haegele, C.W.; B.Sc. (Calgary)
McCarter, B.; B.Sc. (Brit. Col.)
Miller, D.; B.Sc. (Brit. Col.)
Roy, C.
Rosenfeld, L.; B.A. (Manitoba)
Schweigert, J.F.; B.Sc. Hons. (Toronto), M.Sc. (Manitoba)
Stocker, M.; B.Sc. (McGill), M.Sc. (Guelph), Ph.D. (Brit. Col.)

Salmon Habitat

Section Head:

Levings, C.D.[2]; B.Sc., M.Sc. (Brit. Col.), Ph.D. (Dalhousie)

Andersen, B.; B.Sc. (Brit. Col.)

Barnes, D.;

Birtwell, I.[2]; B.Sc. Hons. (London), Ph.D. (Kings College)
Brown, T.G.; B.Sc., M.Sc. (Brit. Col.)
Brown, T.J.; B.Sc., M.Sc. (Simon Fraser)
Choromanski, E.[2]; M.Eng. (Szczecin)
Gordon, R.[6]; B.Sc. (Brit. Col.)
Bravender, B.; B.Sc. (Victoria)
Kruzynski, G.[2]; B.Sc., M.Sc. (Sir George Williams). Ph.D. (Brit. Col.)
Lauzier, R.[2]; B.Sc. (Ottawa), M.Sc. (Simon Fraser)
Macdonald, J.S.[2]; B.Sc. (Simon Fraser), Ph.D. (Western Ontario)
Mack, C.[6]
Martens, D.[6]; B.Sc. (Brit. Col.)
McAllister, C.D.; B.A., M.A. (Brit. Col.), Ph.D. (Washington)
Morton, S.[6]
Ogilvie, V.[6]
Piercey, B.[2]; B.Sc. (Brit. Col.)
Price, D.[2]
Scrivener, C.; B.Sc., M.Sc. (Victoria)
Servizi, J.[6]; M.Sc. (M.I.T.), Ph.D. (Washington)
Shirvell C.; B.Sc. (Alberta), Ph.D. (Otago)
Spohn, S.[2]; B.Sc. (Brit. Col.)
Waldichuk, M.[2]; Ph.D. (Washington)
Whitehouse, T.[2]; B.Sc. (Brit. Col.)
Williams, I.; B.Sc. (Brit. Col.)

Fish Culture

Section Head:

Donaldson, E.M.[2]; B.Sc. (Sheffield), Ph.D. (Brit. Col.), D.Sc. (Sheffield)

Alderdice, D.F.; B.A., M.A. (Brit. Col.), Ph.D. (Toronto)*
Bagshaw, J.
Baker, I.J.[2]; Dip. (BCIT)
Ball, G.H.[4]
Blackburn, J.; B.A. (California)
Booth, M.[2]
Brouwer, D.
Clarke, C.; B.Sc. (Brit. Col.), M.Sc. (Toronto), Ph.D. (U.C. Berkley)
Damon, W.; B.Sc. (Brit. Col.)
Dosanjh, B.[2]; B.Sc. Basic Sci., M.Sc. Biochem. (India), M.Sc. Food Sci. (Brit. Col.)
Dye, H.M.[2]; B.S.A. (Brit. Col.)
Fagerlund, U.H.M.[2]; M.Sc. (Finland)*
Groot, E.P.; B.Sc. (Victoria)
Higgs, D.A.[2]; B.Sc. (Victoria), M.Sc., Ph.D. (Manitoba)
Humphreys, R.M.
Jensen, J.; B.Sc. (Simon Fraser), M.Sc. (Washington)
Johnston, G.E.[4]
Kreiberg, H.; B.Sc., M.Sc. (New Brunswick)
Lamb, A.[2]; B.Sc. (Brit. Col.)
McBride, J.R.[2]; M.A. (Brit. Col.)
Markert, J.R.[2]; B.Sc. (Brit. Col.)*
Morley, R.; B.Sc. (Victoria)
Shelbourn, J.E.; B.Sc., M.Sc. (Brit. Col.)
Solar, I.[2]; B.Sc. (Chile)
Tuck, D.; B.Sc. (Brit. Col.)
Velsen, F.P.*
Withler, R.; B.Sc., M.Sc. (Brit. Col.)

* Left in 1987/1988

Shellfish

Section Head:

Jamieson, G.S.; B.Sc. (McGill), M.Sc., Ph.D. (Brit. Col.)

Bourne, N.; Ph.D. (Toronto)
Boutillier, J.; B.Sc. (Alberta), Teaching Cert. (Brit. Col.)
Carolsfeld, W.; B.Sc. (Victoria)

Fulton, J.; B.Sc. (Brit. Col.)
Harling, W.
Head, S.
Heritage, D.G.; B.Sc. (Victoria)
Noakes, D.; B.Sc. Eng. (Guelph), M.A.Sc., Ph.D. (Waterloo), P.Eng.
Phillips, A.; B.Sc. Hons. (Victoria)
Roy, C.
Whyte, J.N.C.; Ph.D. (Edinburgh)

Ships

Institute of Ocean Sciences

Irving, B.G.; Master H.T.
Parkinson, R.W.; Engineer 1st Class; Member, Institute of Marine Engineers
Fitch, L.A.H.; Master H.T.
Nelson, A.G.; 2nd Mate H.T. (350 Ton Endorsement)
Winterburn, G; Engineer 1st Class; Member, Institute of Marine Engineers
Souliere, V.P.;
Cullen, L.T.**
Doyle, D.A.*
Crayton, M.I.*

CSS JOHN P. TULLY

Newton, B.L., Master; Master, F.G.
Pereira, P. Chief Engineer, Engineer, First Class
Coombes, A.S.; O.N.I
Gimbel, K; O.N.II
Purdie, J.; W.K.M.
Stanway, J.D.; Engineer, 2nd Class
Heesterman, B.N.; Engineer, 3rd Class
Murphy, P.J.
Kirkby, D.
Garneau, G.C.
Law, S.
Keene, A.R.
Graham, D.B.
Aucoin, A.E.
Begin, P.
Boughton, D.G.
Napier, J.W.
Prunkl, W.J.
McRae, A.R.
Smart, T.R.
Brown, D.G.
Bell, C.R.

CSS PARIZEAU

Frost, P.A., Master; Master, F.G.
Redmond, D.A., Chief Engineer**; Engineer, 1st Class
Anderson, J.; Master, F.G.
Elliott, H.G.; O.N.II
Garner, R.; Engineer, 2nd Class
Cooke, B.E.; Engineer, 4th Class
Waterfall, J.P.
Smith, J.R.

Springett, B.R.
Camiot, M.A.
Laforest, B.G.
Scott, R.C.
Fidler, M.J.
Green, J.S.
Palamar, V.

Waistell, G.A.
Kirk, M.J.
Keaveney, T.
Weston, A.*
Begoray, N.
Hendrickson, L.A.

CSS VECTOR

MacKenzie, R.W., Master; O.N.I
Pearson, R., Chief Engineer*; Engineer, 3rd Class
Delaney, K., Chief Engineer; Engineer, 2nd Class
Cadorin, G.D.; O.N.II
Williams, L.E.R.; Engineer, 4th Class
Lavigne, R.
Brown, J.D.

Waistell, G.A.
McKechnie, D.G.
Burns, R.G.
White, R.M.N.
Robie, D.J.
Simpson, F.W.
Anderson, D.D.

CSS RICHARDSON

Bishop, S.O., Master*; Master, F.G.
Wheeler, M.G., Master; O.N.I
Cruseman, R.D.
Jamieson, T.A.

PISCES IV

Chambers, F.J., Chief Pilot*
Holland, R.R., Chief Pilot
Taylor, R.H.
Shepard, K.
Witcombe, A.E.

Institute Workshops

Smith, F.V., Supervisor
Nelson, B.J., Foreman
Bell, W.
Badminton, E.C.
Noren, R.J.S.
Green, G.E.
Williams, P.D.
Ennis, J.F.
Smith, G.J.

Gurney, J.P.
Ingram, T.W.
Barlow, L.
Robson, W.J.

Deck Machinery

Bradbury, J.D.

Shore Patrol and Relief Pool

Campbell, J.O.; O.N.I
Knoblauch, D.E.; W.K.M.
Tran, K.H.; Engineer, 1st Class
Purdie, D.; Engineer, 2nd Class
Simmons, B.R.; W.K.M.
Clark, R.W.
Allison, G.R.
Sanderson, R.L.
Lovelace, R.S.
Fisher, P.R.
Contois, W.M.

Pacific Biological Station

Marine Support

Parks, J.

FRV W.E. RICKER

Ranger, A., Master; Master, F.G.
Fletcher, A., Fishing Master
Hardy, D., Chief Officer; O.N.I
Parfitt, D., 2nd Officer; O.N.I
Alford, E., 3rd Officer; W.K.M.
Swindell, J., Chief Engineer; Engineer 2nd Class
Dillon, R., 2nd Engineer; Engineer 2nd Class Motor
Baldwin, C., 3rd Engineer; Engineer 4th Class Combined
Stevens, W., 4th Engineer; Engineer 3rd Class Motor
Horbas, R.; Engineer 3rd Class Motor
Hunt, T.; Engineer 4th Class Motor
Goodman, K.
McLennan, A.
Ryan, E.
Duffin, D.
Judd, G.
McGladdery, F.
Hickey, R.
Culpepper, D.
Bellerose, E.
Ewing, A.

FRV CALIGUS

Greig, I. A/Master; Master H.T.
Wood, E.

Computing

Institute of Ocean Sciences

Head:

Teng, K.; B.A.Sc., M.A. (Brit. Col.)

Douglas, A.N.; B.Sc. (Victoria)
Foreman, M.G.; B.Sc. (Queen's), M.Sc. (Victoria)
Green, J.W.; B.Sc. (Victoria)
Johns, R.E.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Lee, D.K.; B.S. (Chosun, Korea), M.S. (Oregon)
Lee, K.S.; B.Sc. (Victoria)
Linguanti, J.; B.Sc. (Victoria)
Ma, A.C.; B.Sc. (Victoria)
Oraas, S.R.; B.A.Sc., M.A.Sc. (Brit. Col.)
Page, J.S.; B.Sc. (Brit. Col.)
Smith, L.J.; B.Sc. (Simon Fraser)
Woollard, A.L.; B.Sc. (Victoria)

Biological Sciences

Head:

McKinnell, S.; B.Sc. (Victoria)

Hamer, M.; B.Sc. (Manitoba)
Hamer, T.;
Marshall, M.; B.A. (Brit. Col.)

Communications Branch

Francis, K.L.; B.A. (Victoria) - PBS
Glover, K.T.; B.A. (New Brunswick) - IOS

Management Services Branch

Institute of Ocean Sciences

Chief:

Coldwell, J.H.

Cooper, B.J.
Curtis, J.N.
Doxey, K.
Drysdale, A.E.
Gent, C.E.
Grills, C.J.
Hope, T.
Keding, L.M.
Kroeger, K.
Lafortune, A.J.; B.A. (Manitoba)
Loomes, L.
MacMillan, B.C.
Thomson, L.S.C.; B.A. (Sask.), B.L.S. (Brit. Col.)
Tillie, D.G.
Van Eyk, W.J.

Pacific Biological Station/West Vancouver Laboratory

Head:

Ross, W.B.; Dip. NBIT

Bayntun, G.
Bolton, P.
Booth, B.; Engineer 4th Class
Chu-Joy, H.[2]
Coggins, S.
Hawthornthwaite, M.
Houlihan, C.
Humphreys, S.
Irving, P.
Keller, S.[2]
Matheson, R.[2]
McManiman, D.; Engineer 4th Class
Miller, G.; B.A. Hons (Calgary), B.L.S. (Brit. Col.)
Nagel, D.
Olson, P.; B.A. Hons. (Simon Fraser), M.L.S. (Brit. Col.)
Owen, D.
Palmer, M.
Ranger, E.
Renner, T.; Engineer 2nd Class
Ring, P.; Engineer 3rd Class
Stead, L.; Engineer 4th Class
Tuerlings, J.N.P.[2•]
Vogt, P.
Williams, R.; Engineer 4th Class
Zanatta, Al.[2]

Comptrollers Branch

Institute of Ocean Sciences

Lohrmann, B.A.; B.Sc., M.Sc. (Guelph), M.P.A. (Victoria)

Biological Sciences

Corriveau, J.; B. Comm. (Brit. Col.)

Personnel Branch

Institute of Ocean Sciences

Regional Manager:

Hamilton, K.R.*; B.A. (Brit. Col.)

Personnel Administrator:

Groves, L.D.; Dip. (Victoria)

Knapp, B.M.
Linguanti, S.C.
Olauson, E.J.
Renstrom, M.
Pritchard, E.

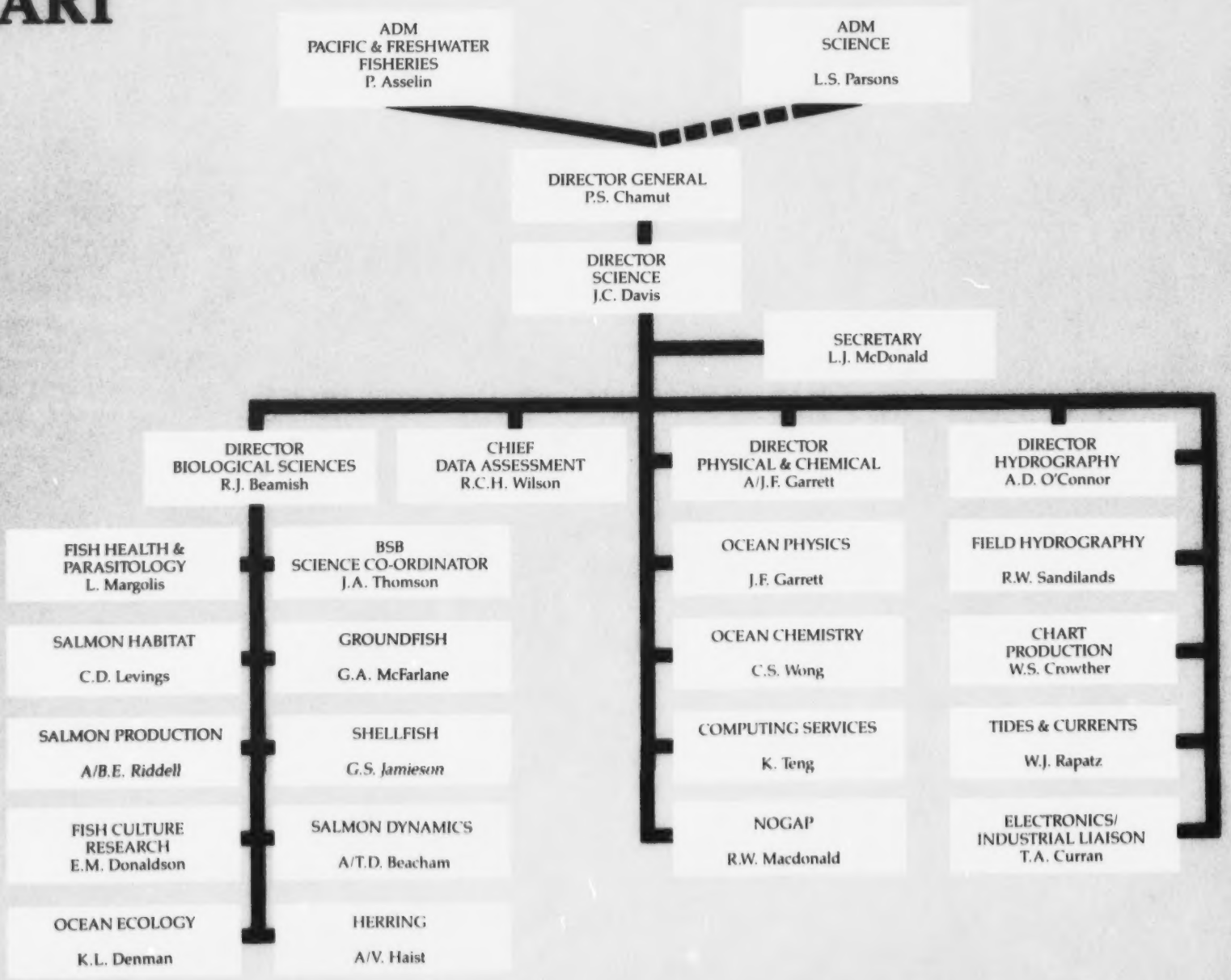
* Left in 1987/88

Biological Sciences

Ford, Debi

---

1 DFO Headquarters, Vancouver
2 West Vancouver Laboratory
3 Prince Rupert
4 Rosewall Creek
5 Vancouver waterfront
6 Cultus Lake
7 New Westminster
8 Institute of Ocean Sciences

ORGANIZATION CHART

Department of Fisheries and Oceans, Pacific Region